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problem of burnout

processing enriched fuel

merican expansion in Europe

June 1961 monthly 3/6

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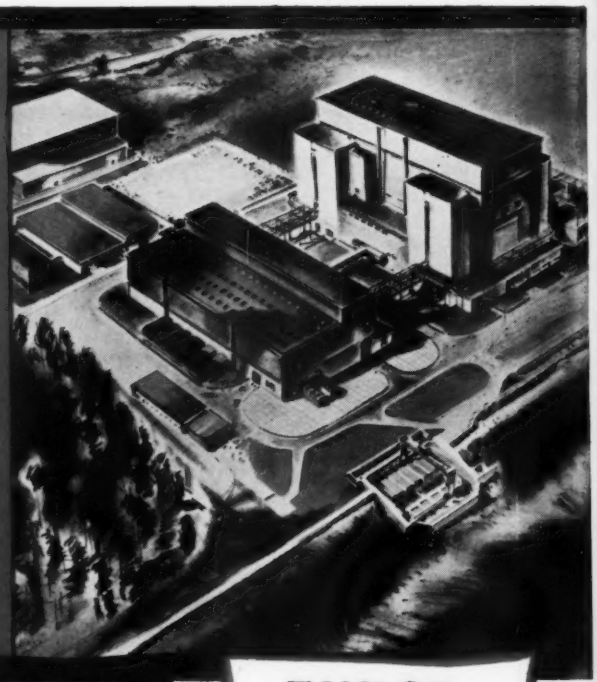

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COVER PICTURE

Inside a shielded cell in one of the highly-active processing plants at Dounreay. See pp 71-76.

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION

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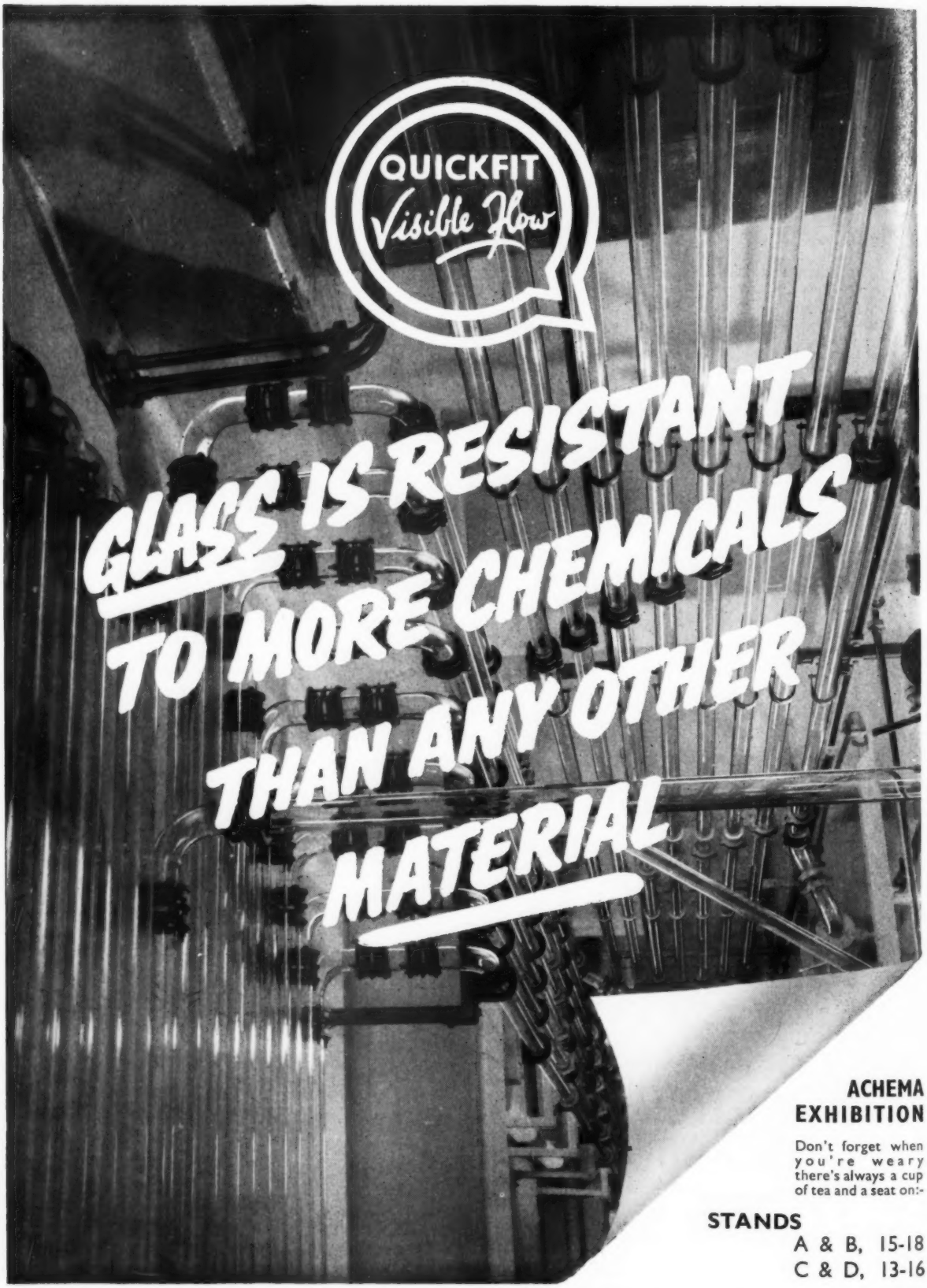

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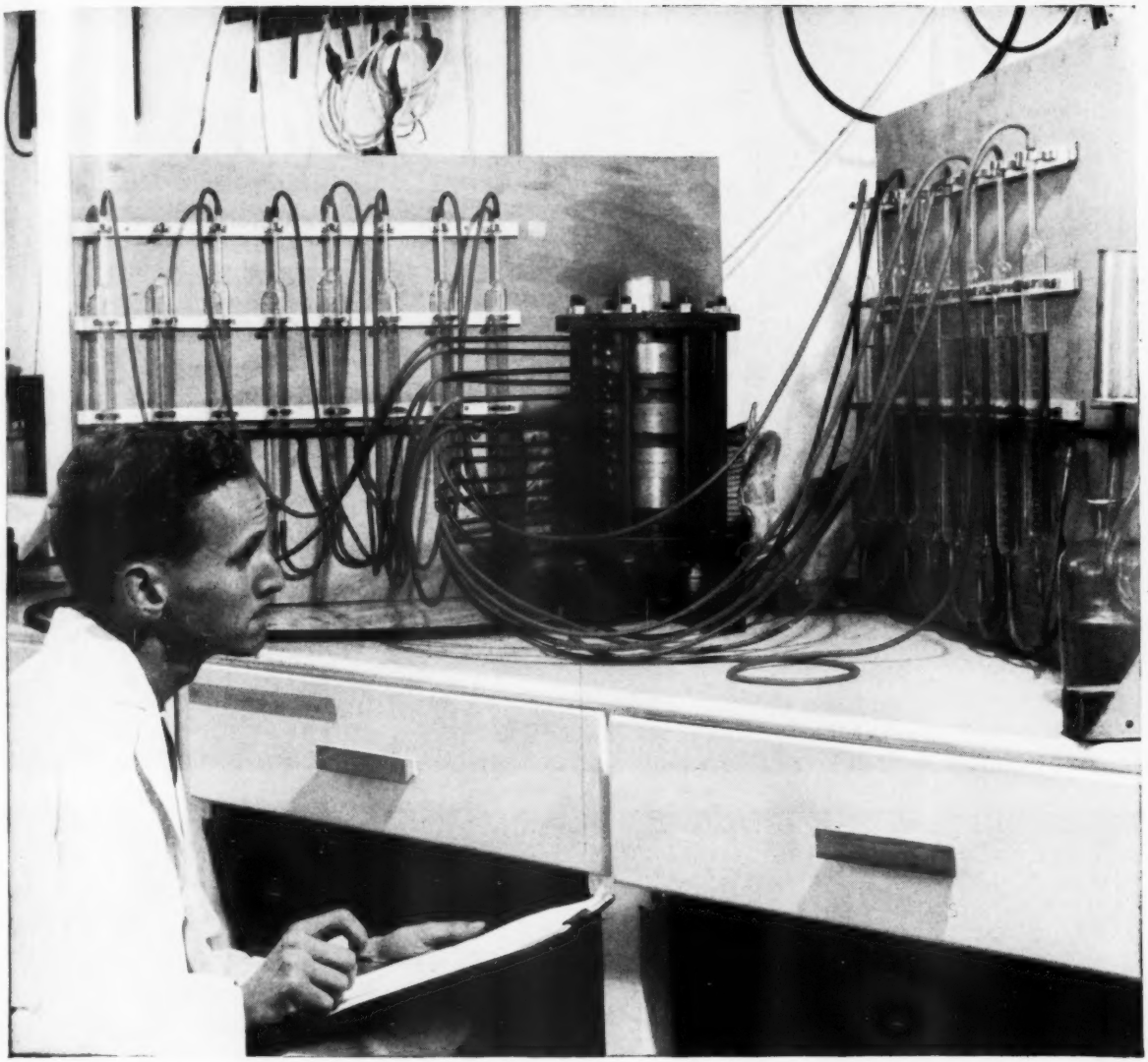

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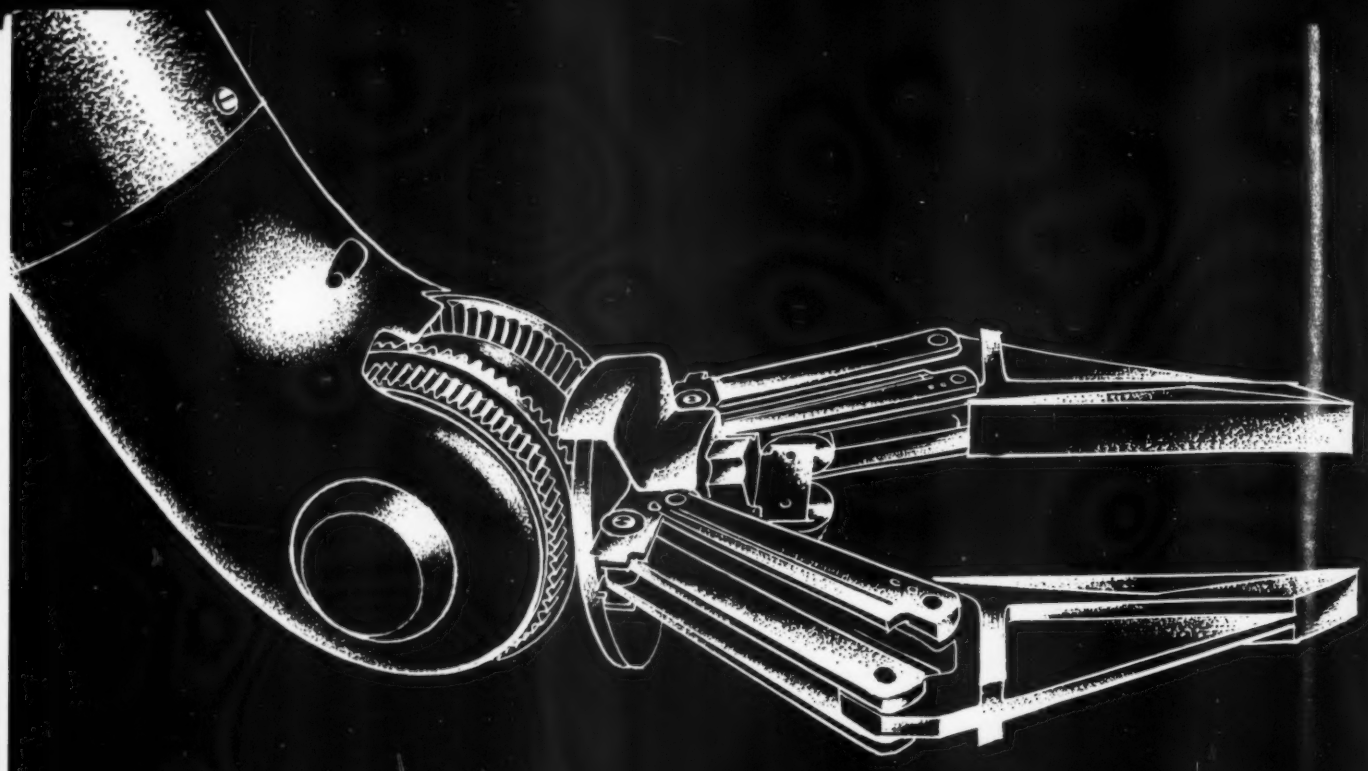

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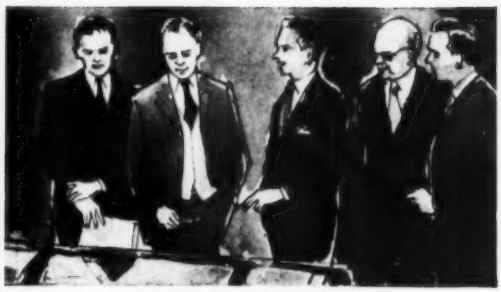
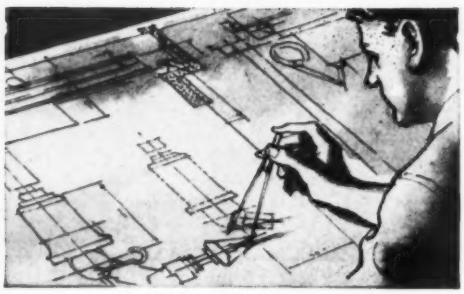
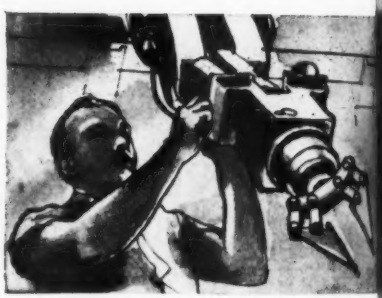


Consultation at the early stage



Preparing the basic plan



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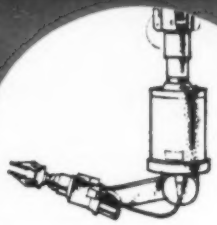
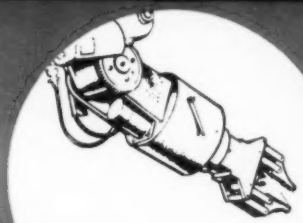


M300 The versatile unit with a lifting capacity from a few ounces up to 750 lb



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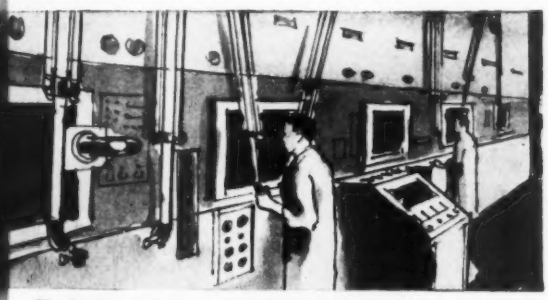

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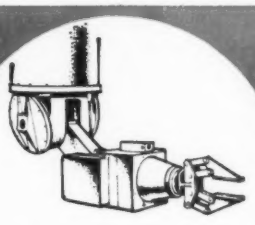
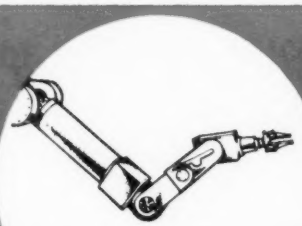
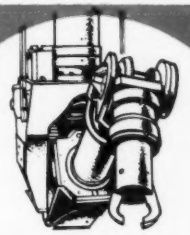


M500 Basically similar to M300 Handles up to 2,000 lb with a fine degree of control



M550 Offers wide versatility in heavy load applications, e.g., 100 lb cantilevered eighteen feet



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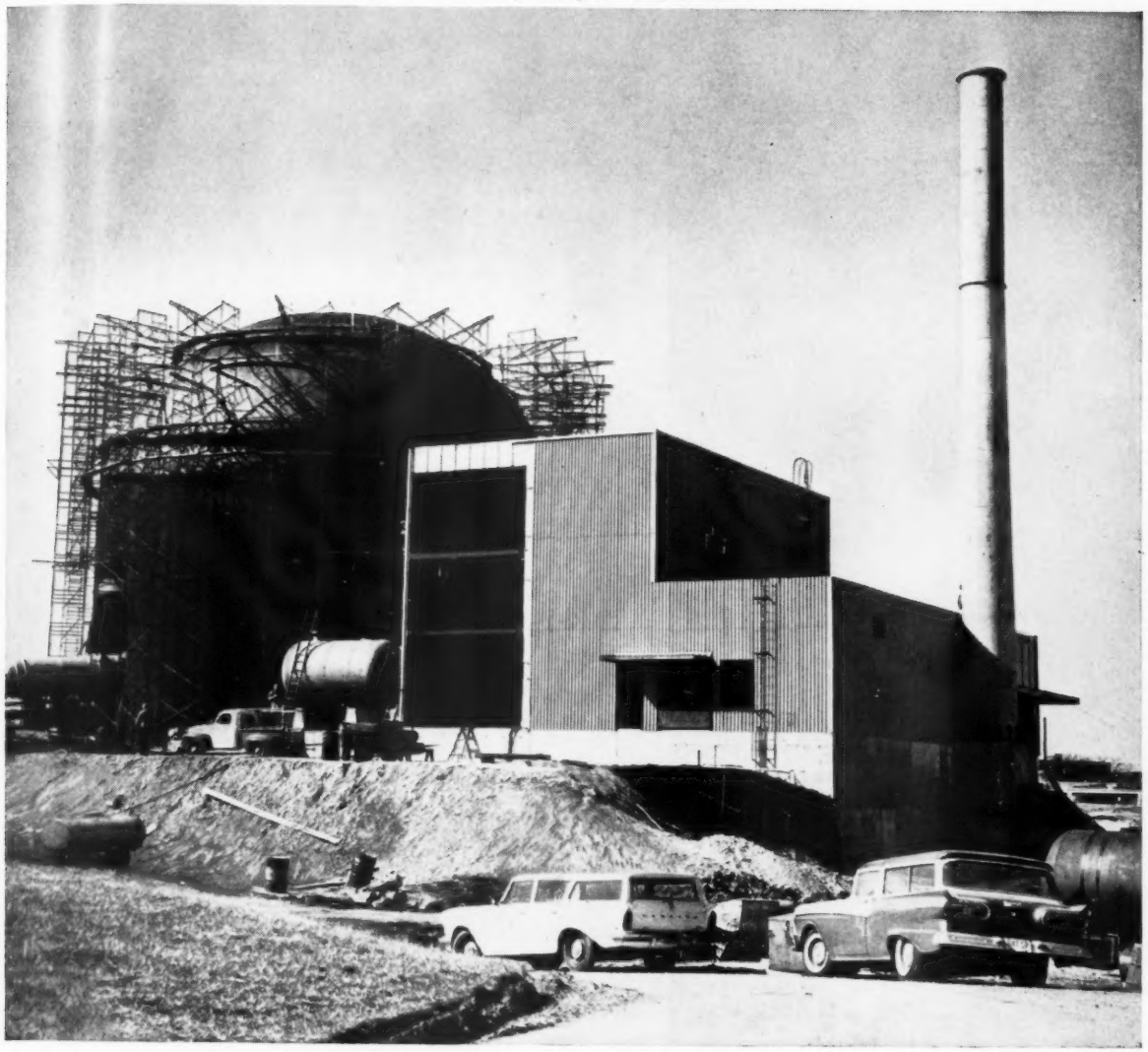

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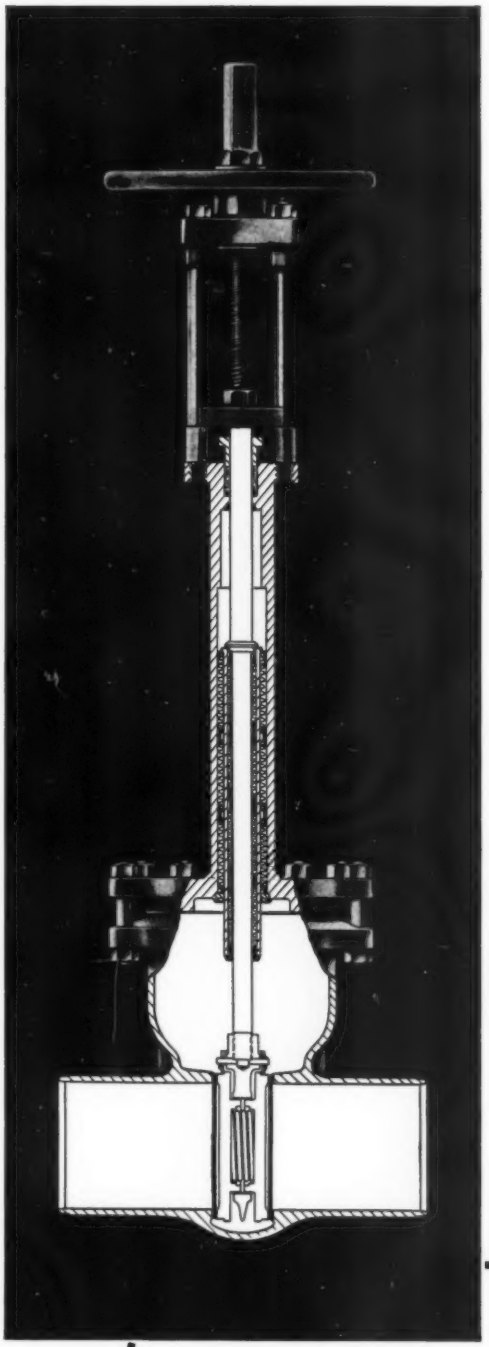

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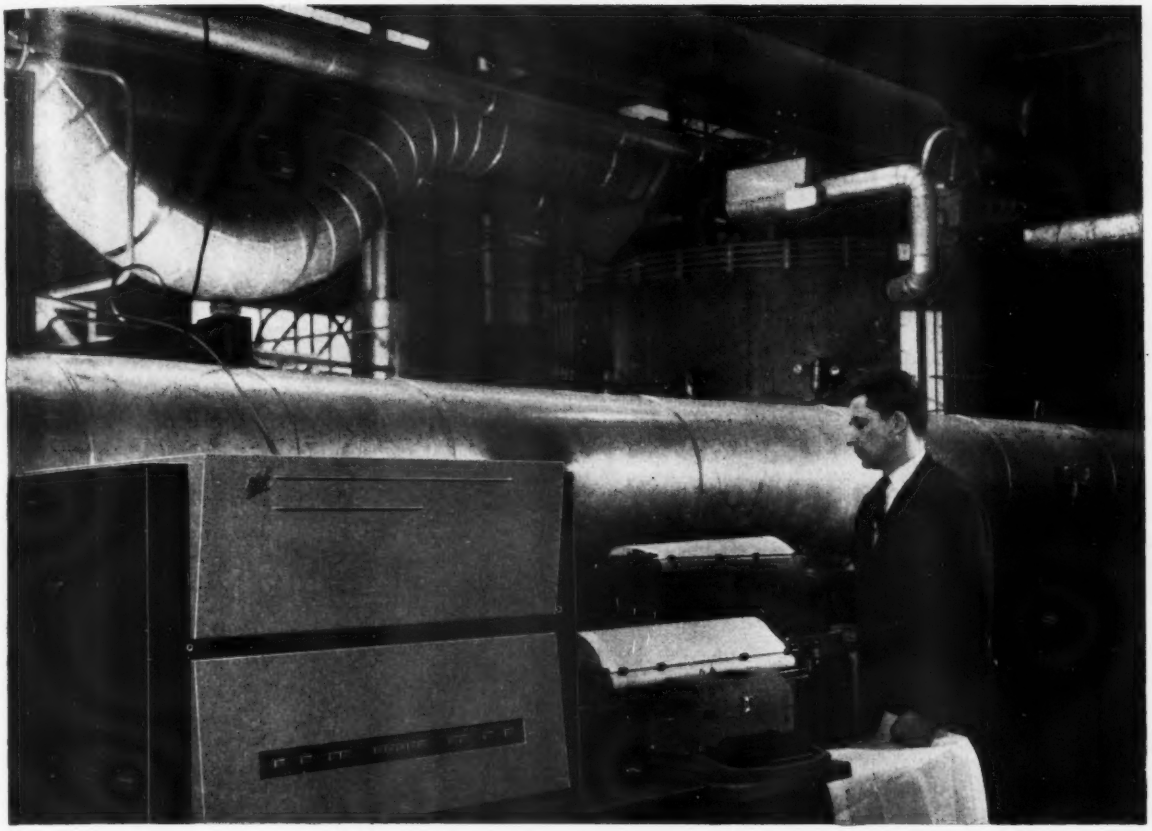

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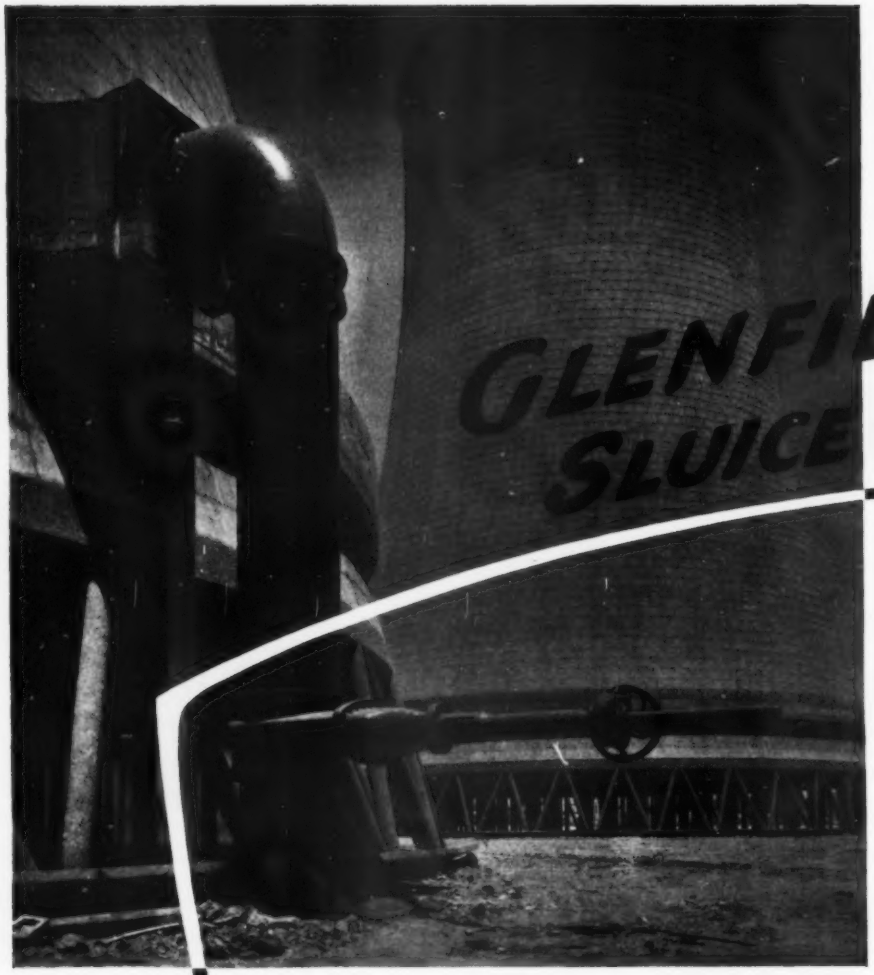

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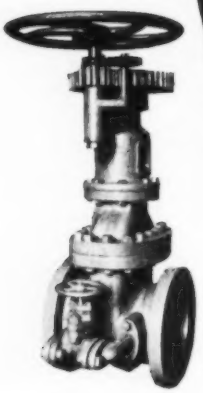

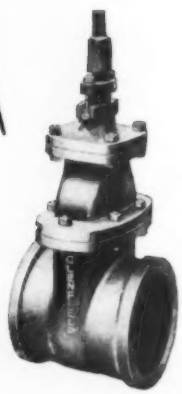

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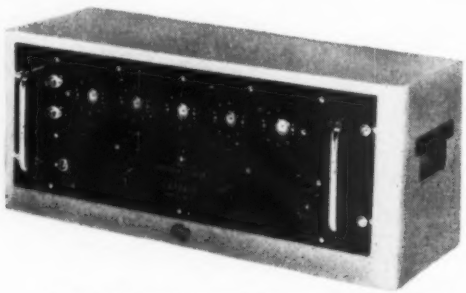

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* Decatronics — a word not yet in the dictionary, perhaps, but "coined" to designate that class of pulse counting and timing techniques developed around the decade counter tube.

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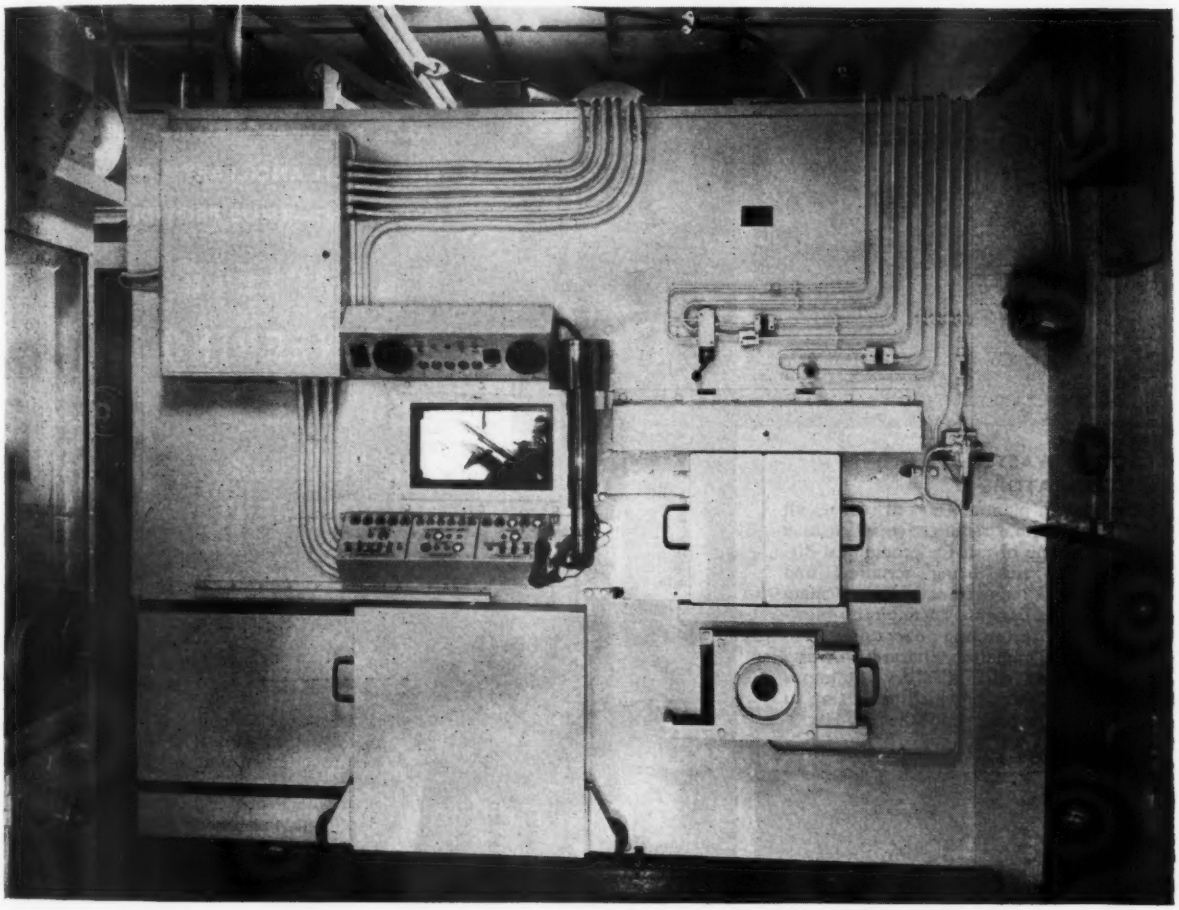

This thoroughly gas-tight $\alpha\gamma$ hot cell for Polonium manipulation has been designed and built for the French Atomic Energy Commission, SACLAY, France.

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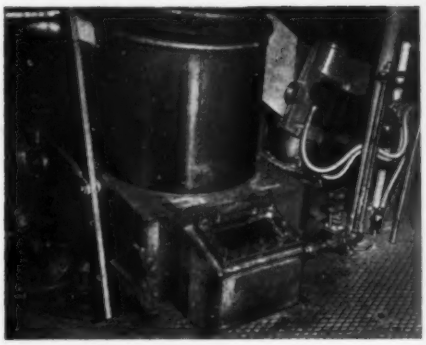

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This stainless steel flask—one of many supplied for DIDO—has a 12" lead wall and is used for extracting irradiated fuel elements from the reactor and transferring them to storage. A self-contained cooling circuit is built into the flask to maintain the fuel elements at a safe temperature throughout all operations.

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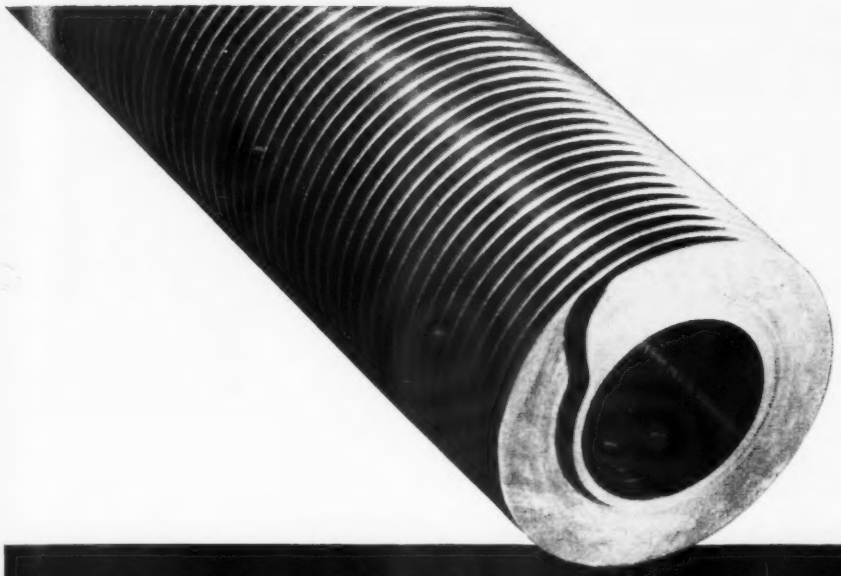
P922



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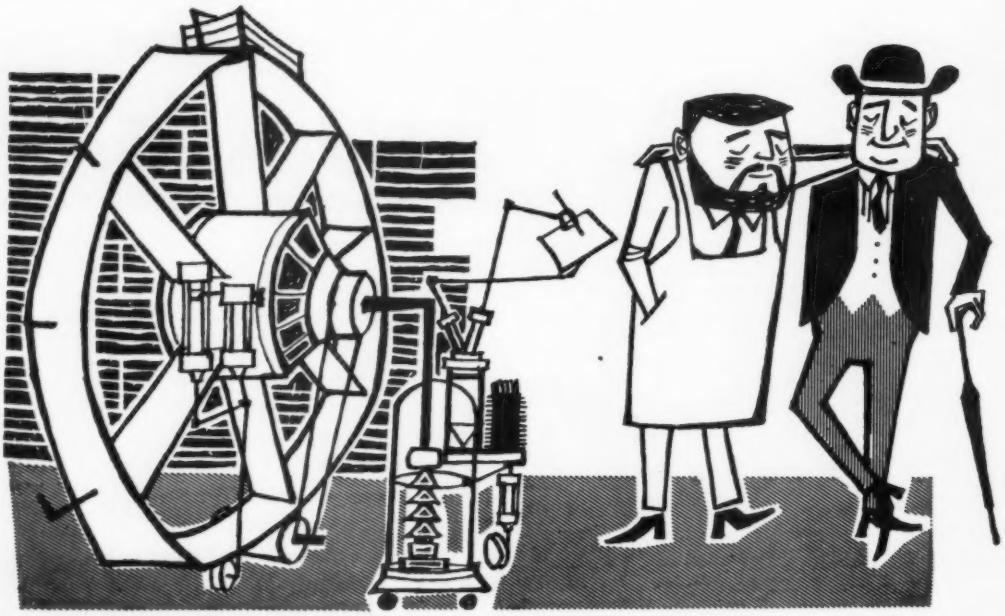

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PNEUTOMATION® stretches the long arm, puts a shoulder to the wheel, works hammer and tongs with might and main, straining every nerve. Boss-class jubilant, production up, costs down, profits, rising. Camaraderie, esprit de corps, bonhomie—everywhere.

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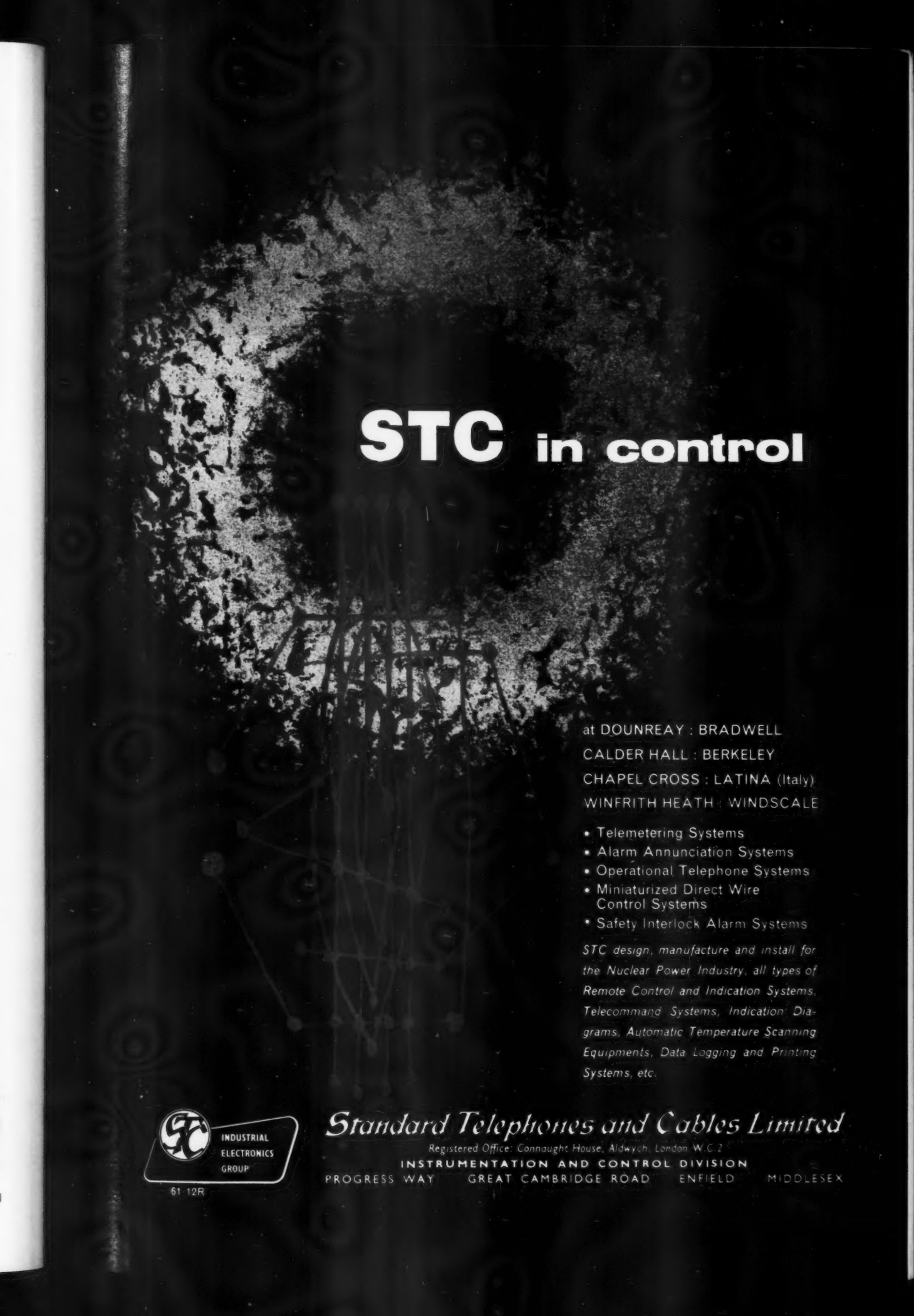
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A heavily screened bench at The Radiochemical Centre for chemistry with radioisotopes.

NEUTRON SOURCES for Nuclear Reactors

Polonium-210 and radium-226 are frequently used as the basis of neutron sources for commissioning nuclear reactors, but another alpha emitter now becoming available for this purpose is thorium-228. For example, this is being used for the Central Electricity Generating Board's power reactors at Bradwell and Berkeley.

	Emission (neutrons/second/curie)	Half-life
POLONIUM-210	2.5×10^6	138.4 days
RADIUM-226	1.3×10^7	1620 years
THORIUM-228	2.0×10^7	1.9 years

Sources of polonium-210 up to 50 curies and radium-226 up to 10 curies are available; supplies of thorium-228 are limited and details of availability will be given on request.

Such sources for reactors must be made to exceptionally high engineering standards. They are supplied in argon-arc welded stainless steel capsules and tested for leakage by helium mass-spectrography. Special sources can be made to withstand operating temperatures up to 800°C.

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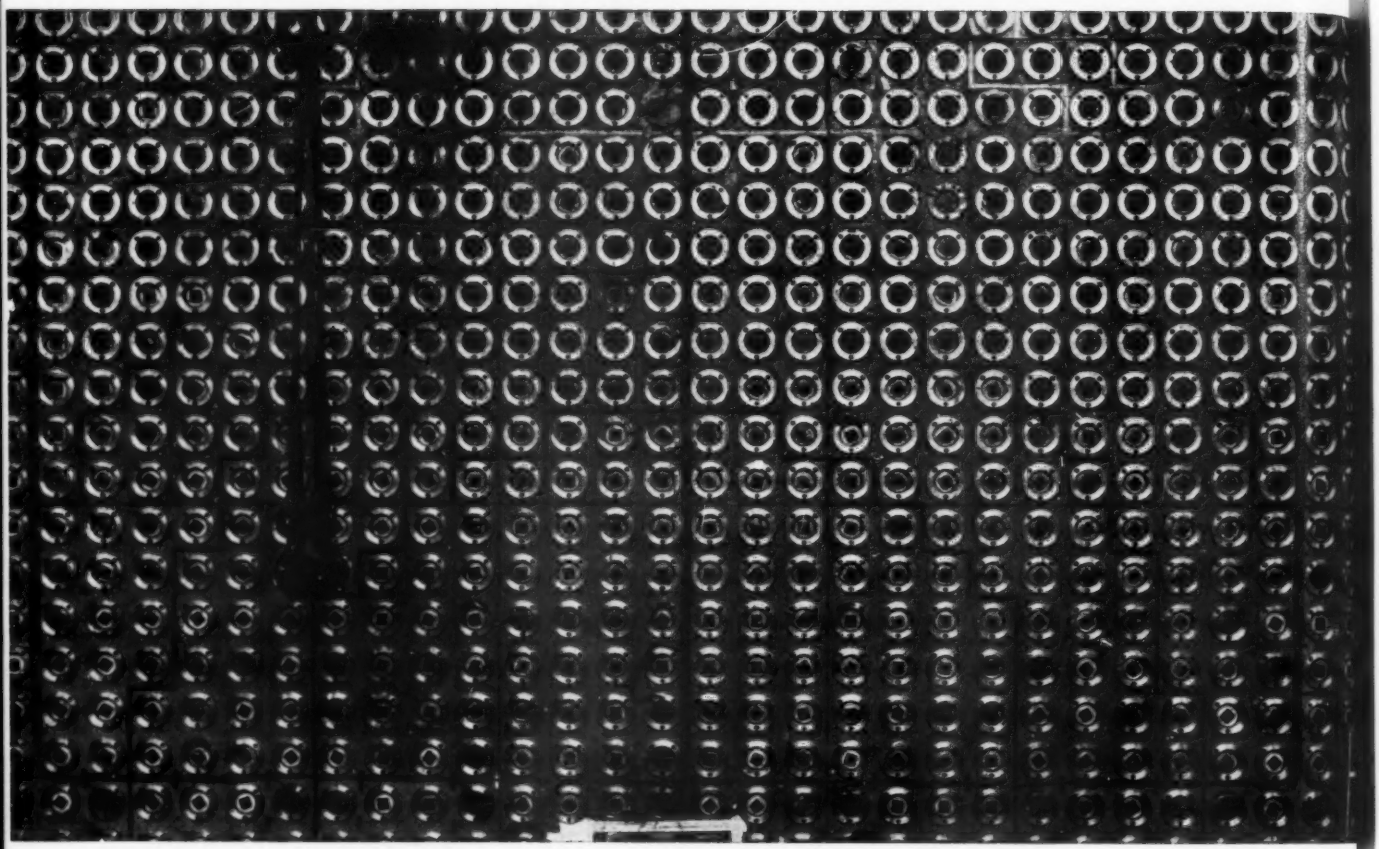

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What would be the cost per day to your business if it were to break down ?

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In this way you can be indemnified against the serious interruptions to your business which can be caused by machinery breakdown.

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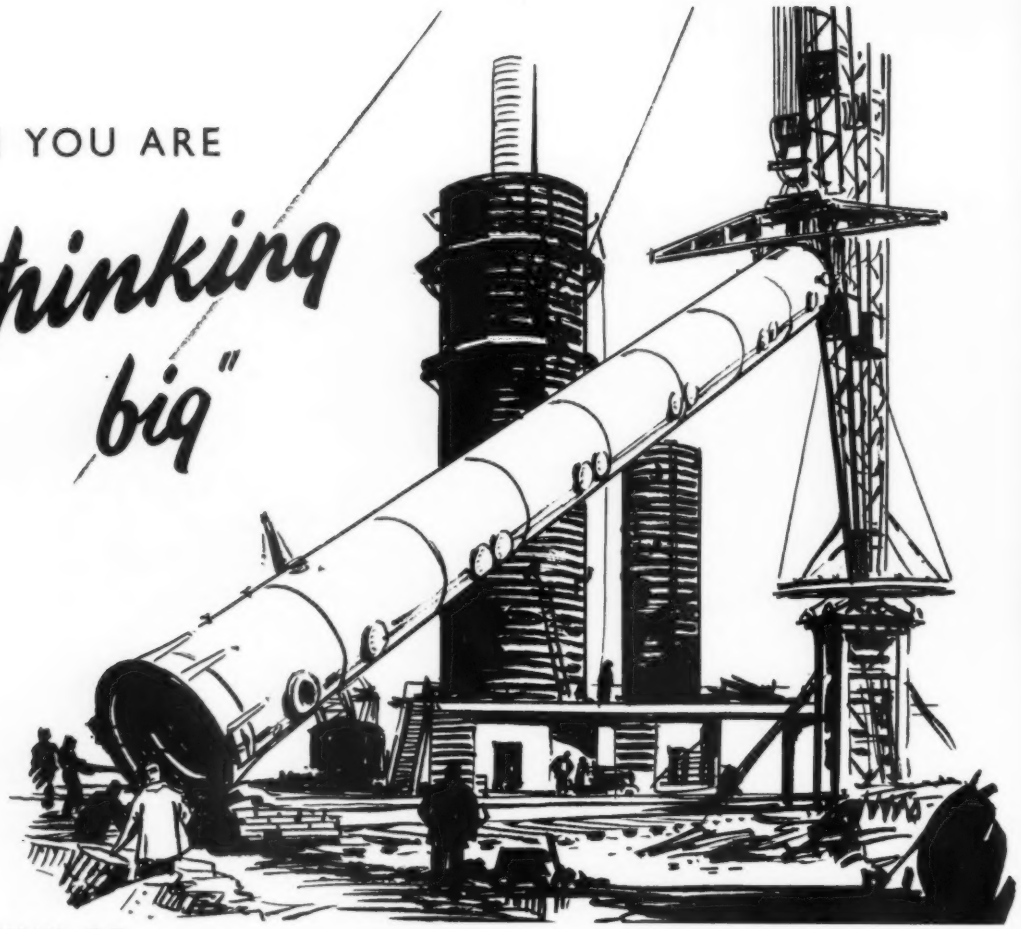

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WITH THE NEW SINGLE HAND MONITOR FOR THE SMALLER ESTABLISHMENT

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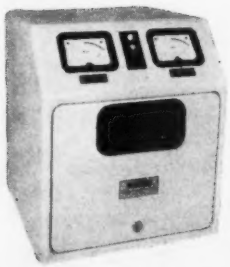
in addition to these brilliantly successful EMI units



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A versatile instrument, whose range has now been extended by the addition of several interchangeable probes. Compact mobility plus high accuracy have been achieved by combining all-transistor circuitry with EMI dual phosphor technique. Battery or mains operation.

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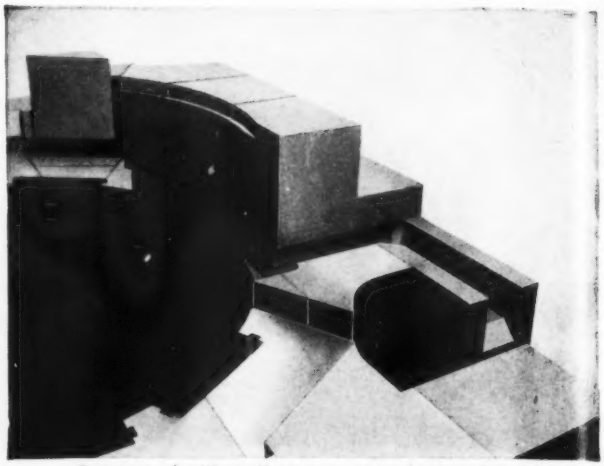

Sections of a "Jason" reactor recently completed for the Hawker-Siddeley Nuclear Power Co. Ltd.

GRAPHITE MACHINING

Powell Duffryn Carbon Products Limited— the leading machinists of Nuclear Graphite.

Official Graphite machinists for the General Electric Co. Ltd. Current contracts cover important work at: Hunterston, Berkeley, Bradwell; also for Hawker-Siddeley Nuclear Power Co. and U.K. Atomic Energy Authority.

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VALVES
for NUCLEAR INSTALLATIONS

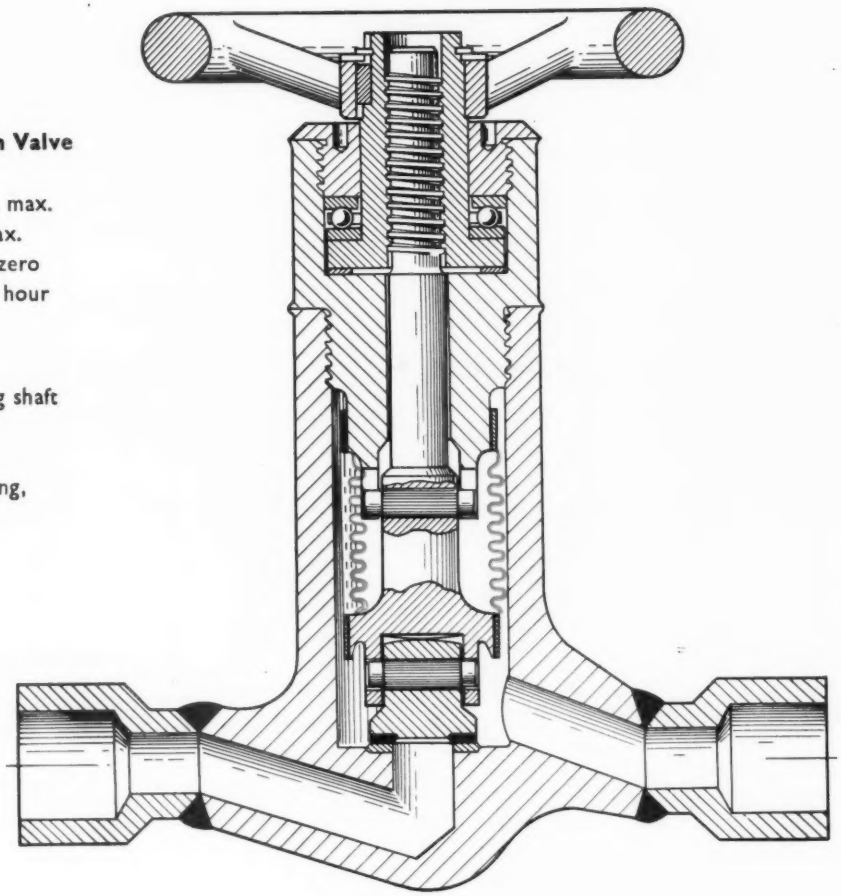
Instrument Isolation Valve

Specification

Pressure 650 p.s.i. max.
Temperature 450°C max.
Leakage to atmosphere zero across seat .001 lbs. per hour at 600 p.s.i.

Special Features

Bellows sealed operating shaft
All joints weld sealed
Back seating
Self-aligning, non-rotating, valve head
Ball thrust bearing
Chrome plated shaft



To meet the need for a satisfactory small bore isolation valve Teddington have engineered this new design now available in standard nominal bores of $\frac{1}{4}$" and $\frac{1}{2}$" and suitable for all fluids normally encountered in nuclear installations.
Teddington bellows sealing ensures no leak to atmosphere. The back seat prevents over movement of the bellows and provides an additional safety feature. A seal cap to replace hand wheel and prevent unauthorised operation is available if required.

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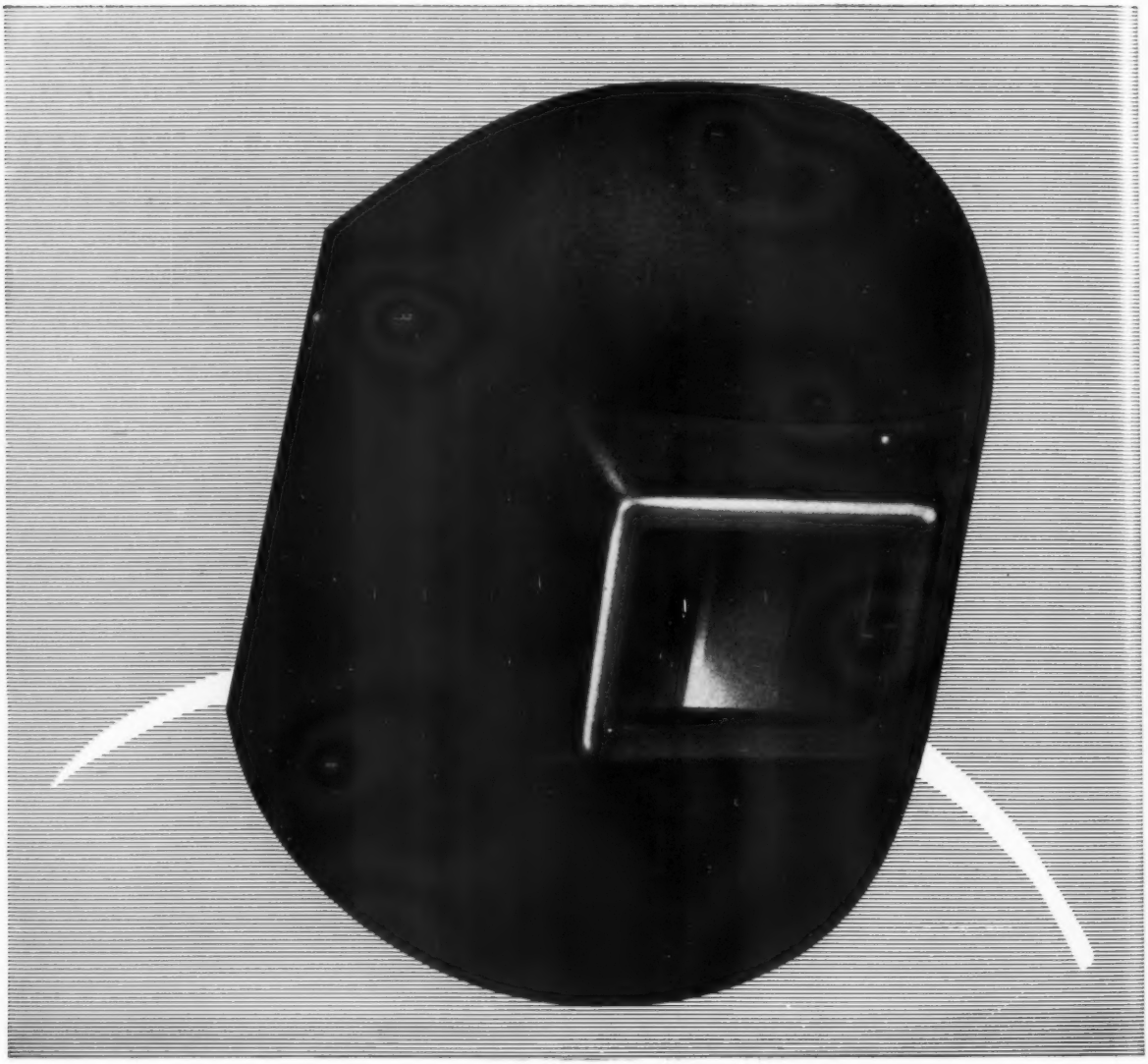

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Most welders prefer Murex helmets because they are right for protection, comfort and strength. They are made of high grade fibre or bonded laminated plastic and are completely shockproof, light in weight and comfortable to wear. Each helmet is fitted with an adjustable headband having an automatic locking device which enables the helmet to be held in the "up" position as long as desired. A patent Murex glass holder provides a dual purpose facility in the plastic type. The coloured filter glass can be raised or lowered in a fraction of a second so that the welder can sight his work right up to the moment of striking the arc.

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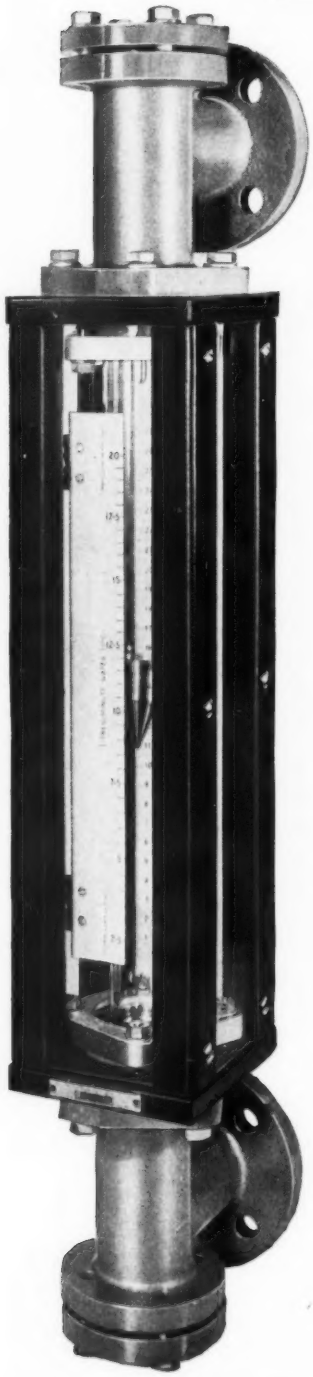
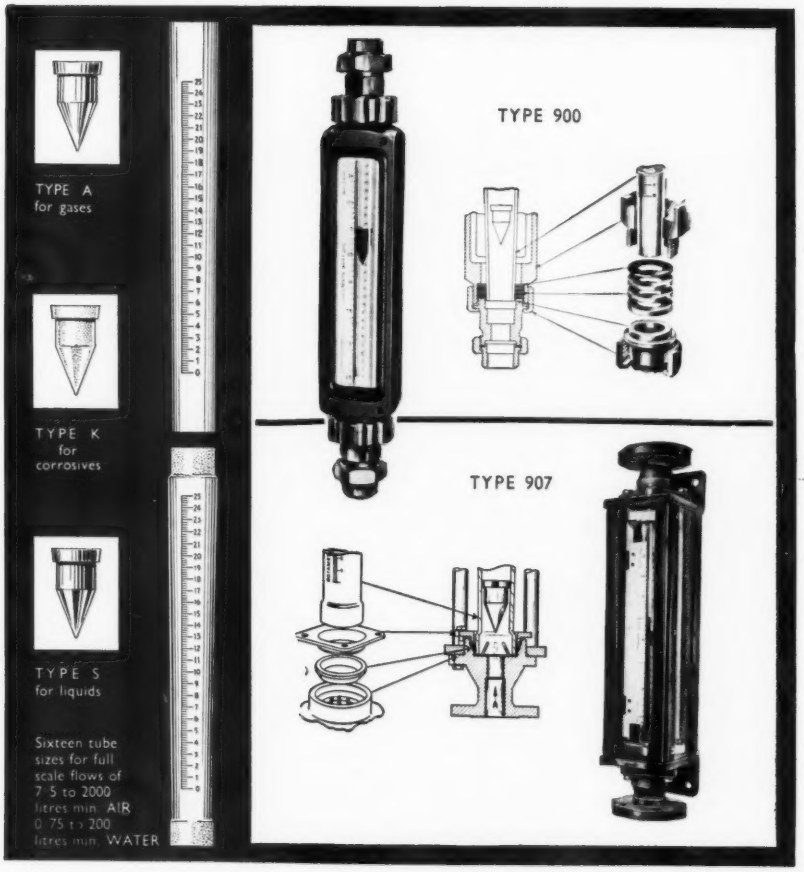
A11/343

This is rationalised flow measurement





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Five sizes of mounting accommodate the sixteen sides of glass metering tube and all have rationalised installation dimensions. Floats of stainless steel, light alloy, or korannite (a ceramic material) and all components are interchangeable for a given size.

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Interchangeable floats of different composition facilitate the conversion of an instrument to meter fluids of different natures; flow scales can also easily be changed as appropriate. These flow scales refer directly to the millimetre scale fused on to the glass tube; they can be provided by the manufacturer or produced by the user from calibration charts.

The type 900 Frame is for low pressure non-corrosive service.

The types 907 and 914 Frames are for rough industrial service and use the Metric 'B' tubes with ground ends and interchangeable gland packing including P.T.F.E. The chassis is a welded structure, nylon covered, and connections are normally of cast iron, stainless steel or rigid P.V.C. Many accessories including a photo-electric alarm can be fitted to these instruments.

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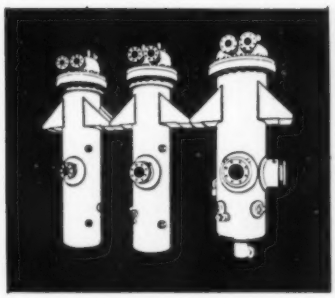

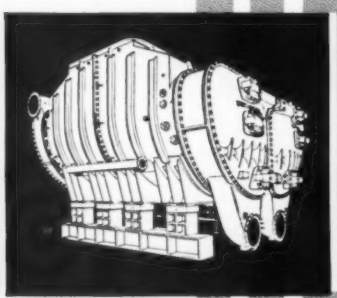

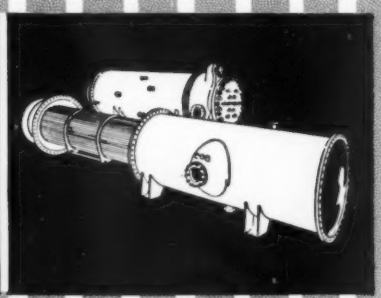

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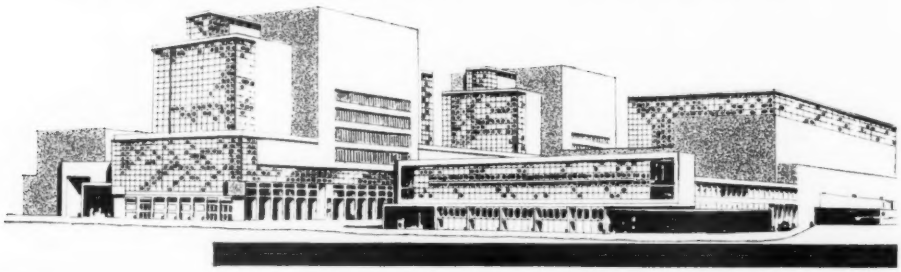
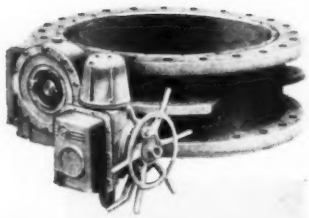
P6010

DUNGENESS
TRAWSFYNYDD
WINDSCALE
Boving
LOW-PRESSURE BUTTERFLY VALVES





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are being utilized in the Condenser Cooling Systems at Dungeness and Trawsfynydd and in the Advanced Gas Reactor at Windscale. Boving Butterfly valves are compact and drop-tight, sealed by automatic inflation.
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VALVES SUPPLIED		SIZE INCHES
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	8 " "	54
	8 " "	60
	4 " "	72
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TRAWSFYNYDD	4 electrically operated	42
	8 " "	72
WINDSCALE	2 electrically operated	36

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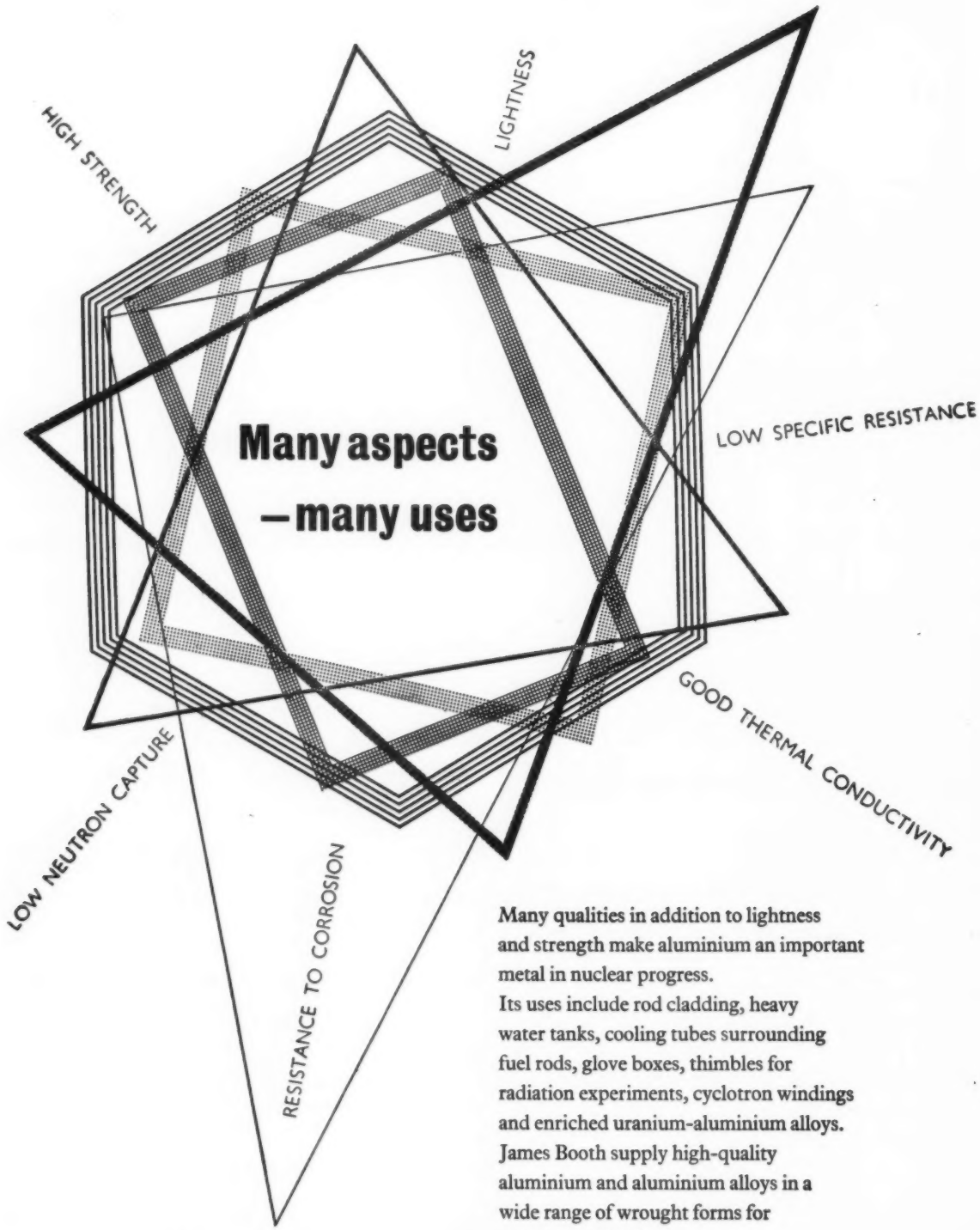

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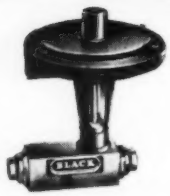
For use on gas/air.



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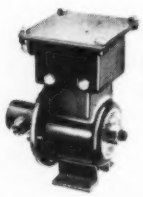

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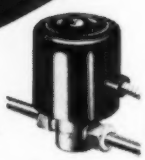

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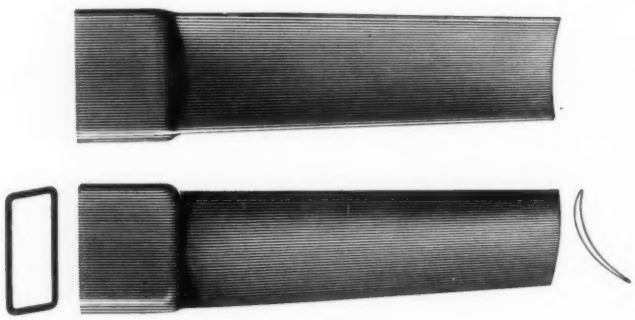
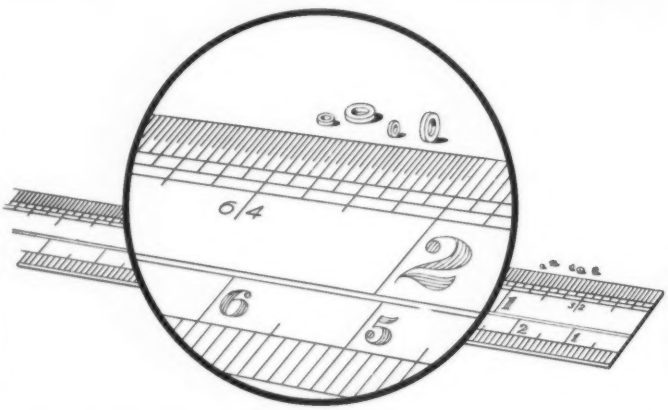
The wall thickness is $\frac{1}{16}$" at the platform end and tapers to $\frac{1}{64}$" at the opposite end.





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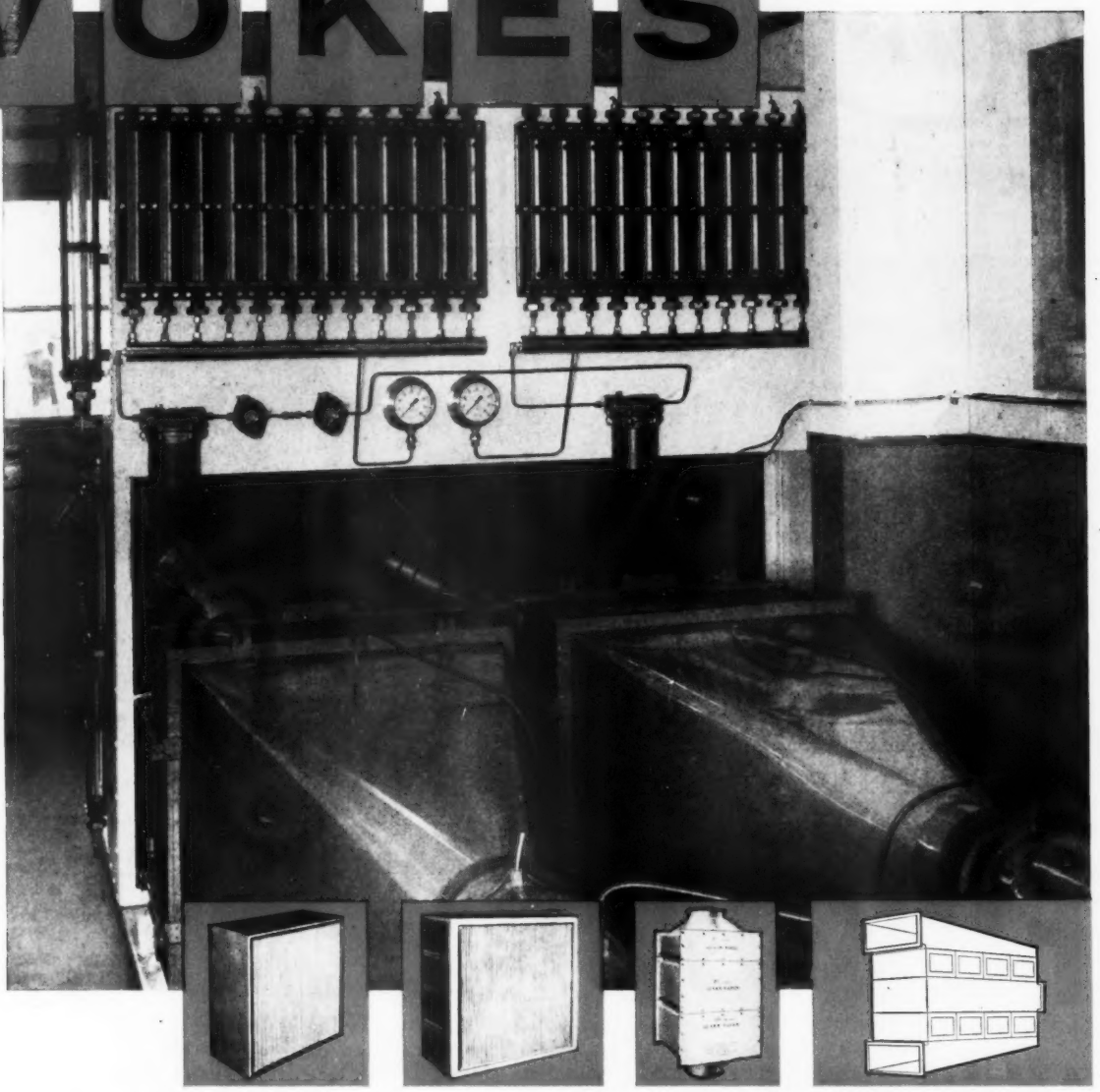

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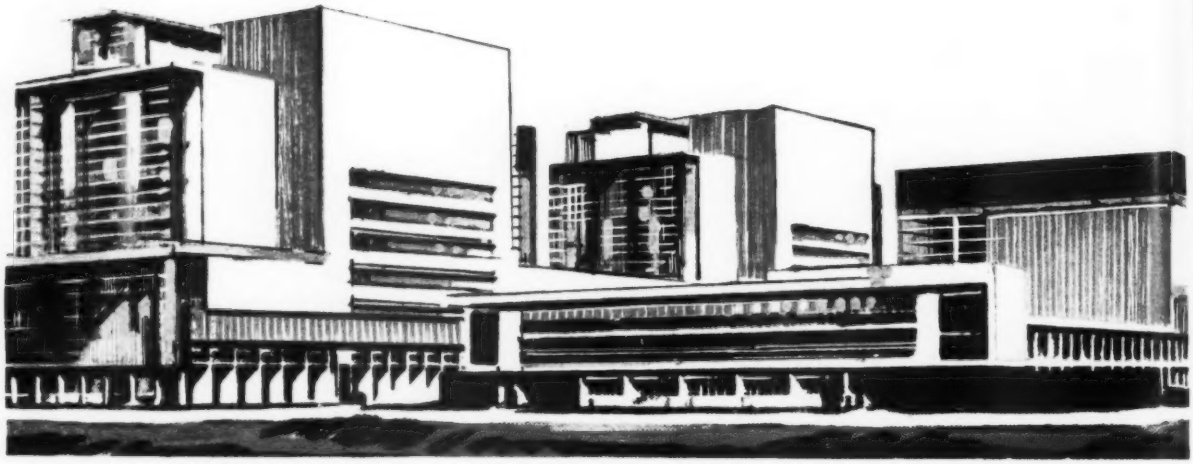

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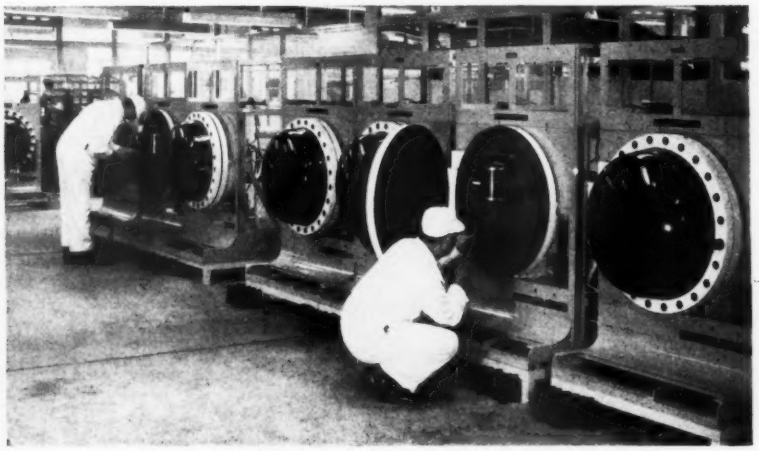

Clean area BSD equipment manufacture

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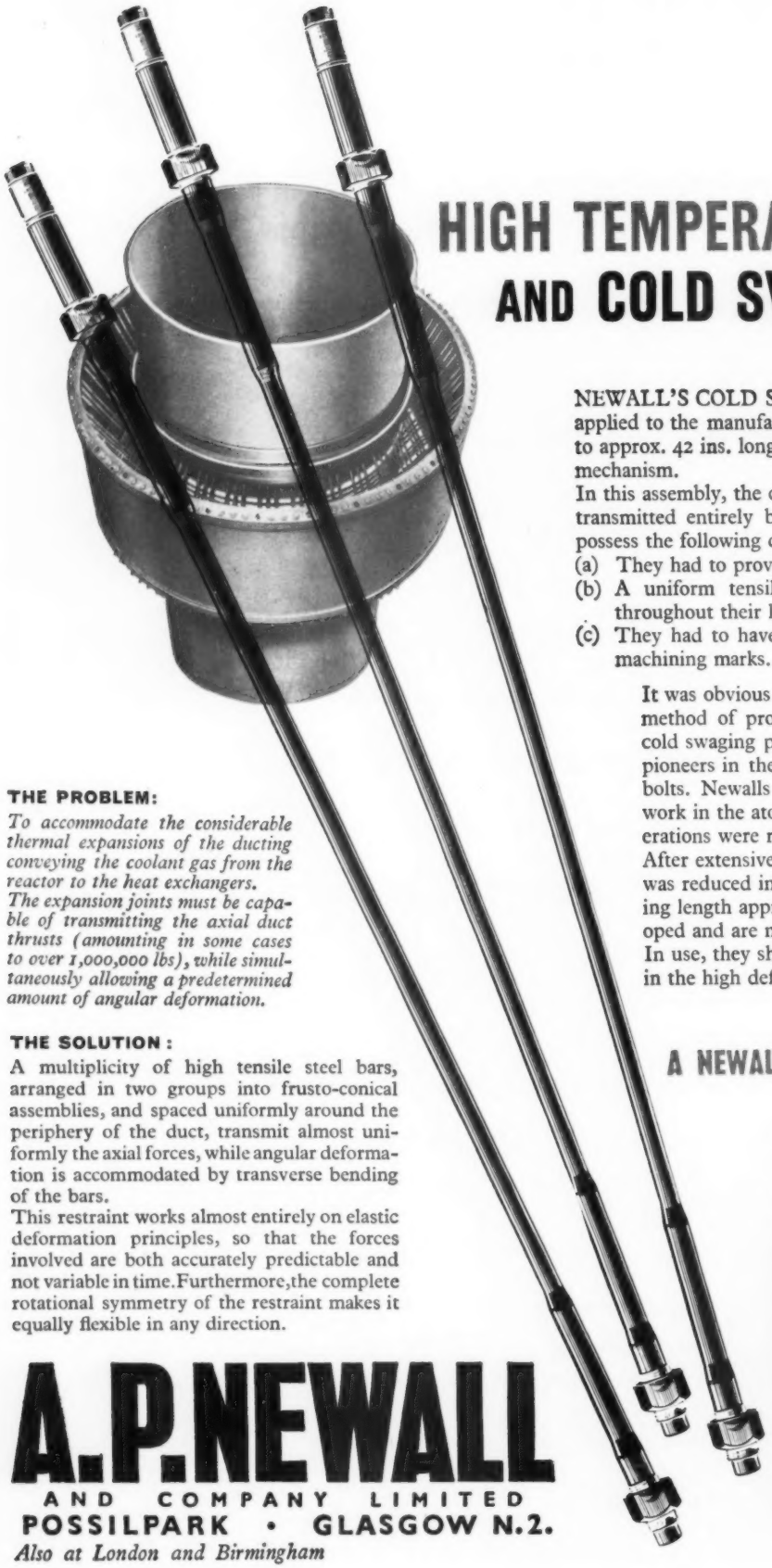

HIGH TEMPERATURE DUCTS AND COLD SWAGED BARS

NEWALL'S COLD SWAGING PROCESS was recently applied to the manufacture of high tensile steel bars (up to approx. 42 ins. long) for use in a new bellows restraint mechanism.

In this assembly, the considerable operating pressures are transmitted entirely by the tension bars, which had to possess the following qualities :

(a) They had to provide a high degree of flexibility.
(b) A uniform tensile strength of approx. 75 tons throughout their length was required.
(c) They had to have a surface completely free from machining marks.

It was obvious therefore that the most satisfactory method of producing such bars was by Newall's cold swaging process, as this company have been pioneers in the manufacture of swaged studs and bolts. Newalls were actually associated with early work in the atomic field when certain swaging operations were required in the planning of Harwell. After extensive experiments, during which a blank was reduced in diameter by approx. 30% (increasing length approx. 40%), the bars have been developed and are now incorporated in the mechanism. In use, they show "extremely high fatigue strength in the high deflection range."

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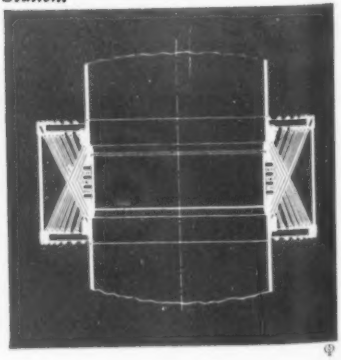
A NEWALLASTIC PRODUCT

Below and at Top Left : Bellows Restraint Mechanism, designed by Richardsons, Westgarth & Co Ltd, for the Trawsfynydd Nuclear Power Station.



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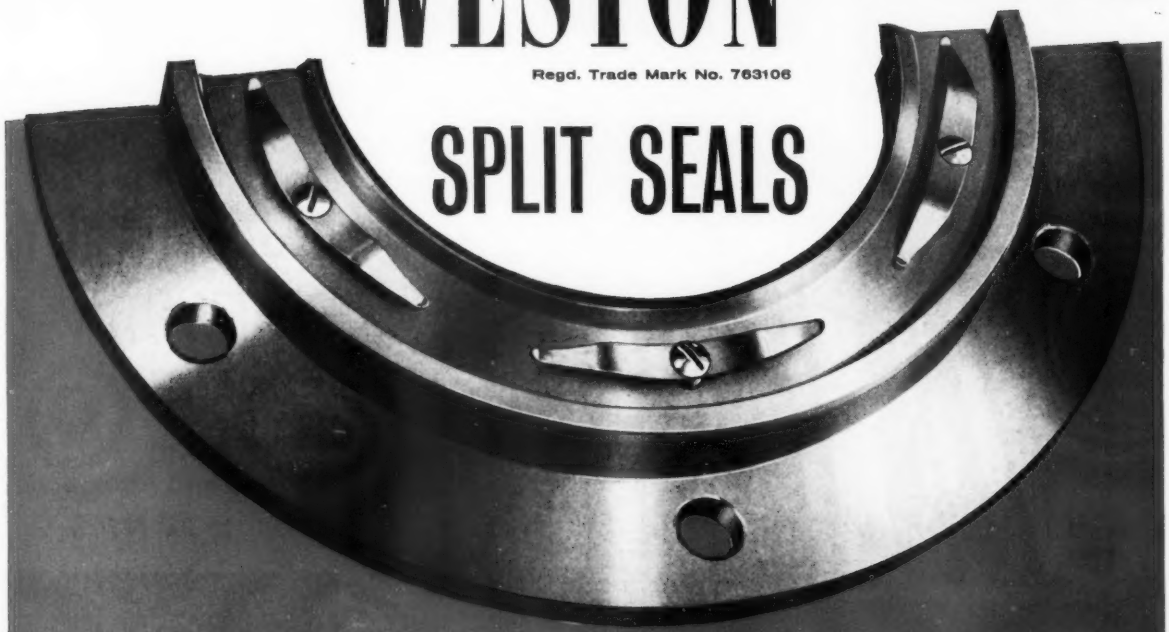

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Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

JUNE 1961 VOLUME 6 NUMBER 62

VIEWPOINTS letters to the Editor

Radiation hazards

SIR: The reference in your May issue (p 54) to the need for full guidance from the Ministry of Transport on the carriage of radioisotopes prompts me to point out that with the increasing use of X-rays and isotopes, the good radiation safety record in this country will have to be maintained by further means than is at present embodied or envisaged in legislation. This association has advocated comprehensive legislation to cover risks from radiation for some years now. It is, indeed, the policy of the Trades Union Congress. However, the Government, as far as we know, has not accepted this even as a long term goal; it prefers to rely on legislation for factories and voluntary adherence to codes of practice elsewhere.

Presumably, the underlying assumptions are that establishments other than factories are historically not places where industrial hazards will normally occur and that the use of radioactive substances in such places will be confined to those who understand their nature. But in fact, laboratories outside factories probably use such substances more widely than in factories. Laboratory staffs, indeed, may well be subject to much more prolonged exposure than the factory worker. Understanding of a hazard is not always conducive to a willingness to accept and operate safe and often onerous techniques. Protection is also needed for the bystander.

The recent Ionizing Substances Regulations have been too long in preparation. Apparently, one reason is the praiseworthy acceptance of the need to consult interested bodies and the undue prolonging of such consultations. Another may well be a desire for perfection when the subject calls for decision and a subsequent flexibility in altering regulations as knowledge and experience is gained.

The Hospitals Services' Code of Practice has recently been followed by a code of practice for universities and the Ministry of Labour has an advisory committee looking at other non-industrial establishments where the hazard exists. The regulations and the codes have minor differences and must be based on the same essential premises and protective measures. But one has the force of law and the other that of good intention only. It should be recognised by the Government that with this new and insidious hazard, all workers need statutory protection and all employers the same obligatory stimulus to the operation of maximum protective measures. The limitation of statutory protection against industrial hazard to factories ignores the changed characteristics of research establishments.

JOHN K. DUTTON
GENERAL SECRETARY

The Association of Scientific Workers, London, W.1

B.S. Abbreviations

SIR: I feel that some reply is required to L. O. Gittings' letter in the May issue, in which he asks if there is necessity for distinguishing between the units of force and mass. To anyone who has considered this, the answer is quite obvious, but for those who have not, perhaps some guidance should be forthcoming.

The recommendation from the British Standards Institution to distinguish between units of mass and force was made a long time before last October and, even then, the Institution was not the source of the recommendation. It is the abbreviation lbf that has recently been suggested, in accordance with the International Organisation for Standardisation, in place of lb which has been in common use for many years in this country.

The acceleration of a 1 lb mass acted upon by a standard force of gravity is 32·174 ft/s². From Newton's second law, proof of which, I hope, is not required, the force on that 1 lb mass is proportional to 1 lb × 32·174 ft/s². In defining the unit of force, the constant of proportionality is taken to be unity and the name given to it is the pound force, 1 lbf. Thus 1 lbf = 1 lb × 32·174 ft/s². If this unit is termed 1 lb, then 32·174 ft/s² = 1 which I am not prepared to believe even if Mr Gittings is.

One can get into serious trouble if the units of both are the same, as the force of gravity on a 1 lb mass is not constant; Yuri Gagarin can confirm this by experience.

I would like to ask Mr Gittings how to get along very nicely with 'psi' as I could not possibly do so. How does one, for instance, find the units of a quantity which contains 'psi' multiplied by other units involving force and length?

D. C. HICKSON
LECTURER

College of Advanced Technology Birmingham

Fuel handling

SIR: Referring to the comments passed by Mr R. F. W. Guard in his letter (*Nuclear Power*, May) regarding the pros and cons of on-load refuelling equipment, although the Calder Hall reactors are recognized as the forerunners of our current commercial stations, surely this achievement of operating at full-belt for over 300 days on a relatively low-powered reactor cannot be truly indicative of any future operational performance of the much larger and more powerful civil installations.

The statement, readily agreed, that we are only on the threshold of obtaining information on the behaviour of industrial fuel elements, surely leads to the realisation that burst elements will remain a problem for some time to come.

When the aim is to obtain the maximum burn-up of the fuel for obvious economic reasons, it would therefore seem to be an important necessity to provide equipment to remove faulty elements whilst the reactor is on-load, and, if this equipment is installed, why not use it for normal fuel handling as well?

The possible advantages of shuffling, both radially and axially, of the fuel elements should also be taken into account.

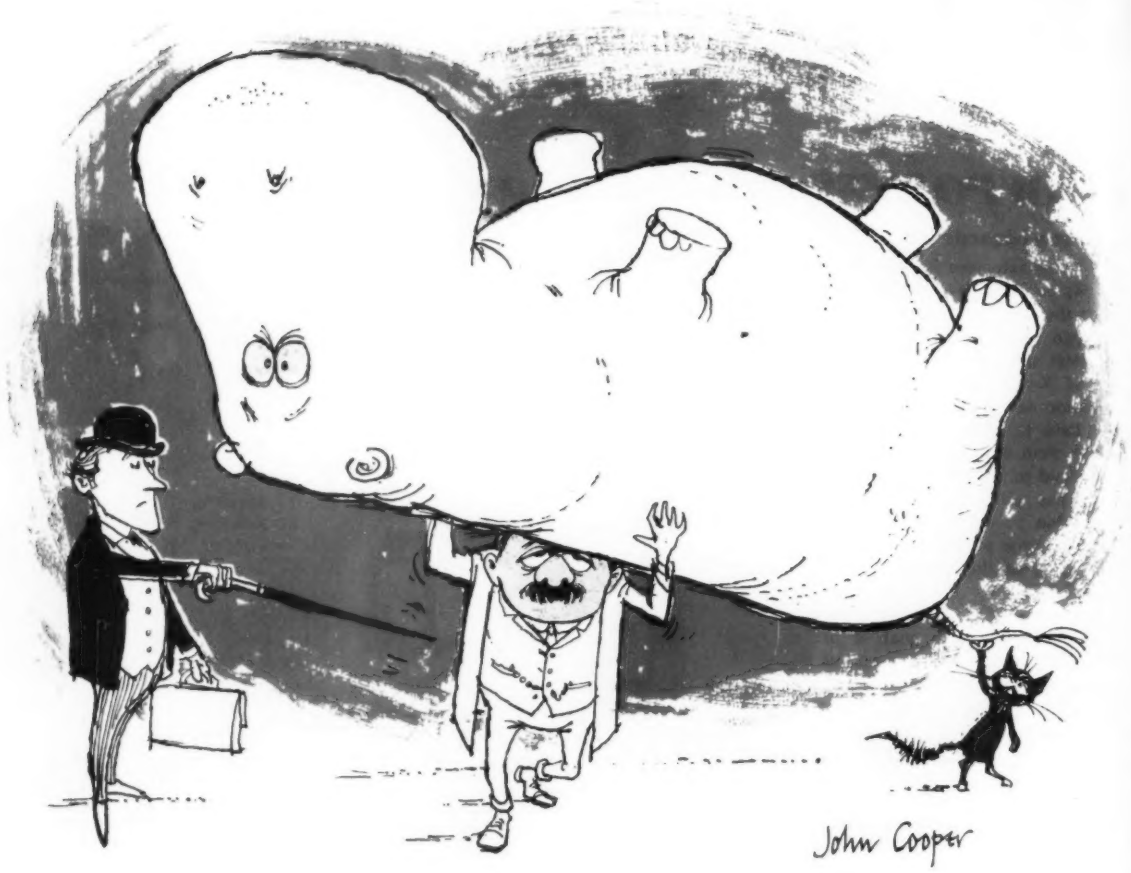
A. D. WORDSWORTH
Babcock & Wilcox Ltd

Trawsfynydd

SIR: I have only just recently studied the World Reactor Chart in the January 1961 issue of *Nuclear Power*. Against item 11—'Trawsfynydd'—I note that the location is North Wales, ENGLAND. Since when, may I ask, has this part of the Principality of WALES been in ENGLAND?

G. J. RICHARDS
Hawker Siddeley Nuclear Power Company

Blin gennym am y camgymeriad.—Editor



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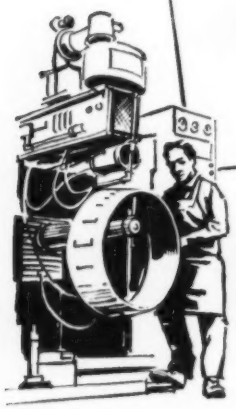

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OPINION

Euratom and UK fuel exports

THE LOSS OF UK fuel element business to the tune of over £5 million followed by around £1 million per annum could be the outcome if the present proposal for Euratom subsidies is approved. (See *Worldview* page 53.) This proposal, sparked off by the Italians and forming part of the drive towards hastening the growth of the Common Market's nuclear industries, intends to divert nearly £7 million from Euratom's annual research budget to subsidize the initial fuel costs of the three Euratom nuclear power stations: Latina, Garigliano and Chooz.

Latina, of course, which has been designed and engineered by The Nuclear Power Group for the Italian consortium SIMEA, is the only station which concerns the UK Atomic Energy Authority. The fuel for the other two stations, to be built under the US-Euratom Joint Power Reactor Programme, as yet is to come from the US Atomic Energy Commission.

SIMEA apparently told Euratom that the placing of the Latina fuel contract with a company within the Six was practicable; but with the first loading of 290 tonnes scheduled by next April, it is difficult to see how anyone other than the Authority can cope with the situation, particularly in view of the Italians' vaccilations over signing a contract; it should have been signed a year ago. Some people think that one reason for SIMEA'S dilatory attitude is that they are going to find it difficult to get rid of the electricity generated and that they are playing for time.

Italy delays

Nevertheless, SIMEA is now said to have had second thoughts on the matter and to be proposing that the initial charge be brought from Britain but that the replacement fuel, 65 tonnes annually, be purchased from a French company. A recent tender put out resulted in a number of bids and whilst the UKAEA price was not the lowest, none of the others could match the Authority's performance guarantees on buy-back price. The loss of business of this magnitude would naturally be a disappointment to the AEA, who have been given a lot of trouble over the Latina fuel contract, but presumably they would not be sorry to see the matter settled once and for all. In any case, the Authority has always felt that it could not expect European fuel orders to come to them indefinitely. In January 1959, Sir William Cook stated that they were willing to grant 'at the appropriate time' normal commercial licences to countries wishing to make their own fuel elements for British reactors.

Nevertheless, under the circumstances, it is difficult to see why this situation has arisen. For a European firm starting from scratch, the building of a fuel element fabrication plant could well be prohibitive. After paying what presumably will be a considerable amount to the UKAEA for the 'know how', an additional £1-2 million will be required for a plant equipped specifically to make one type of fuel element. At the moment there is only one definite British-type reactor going up; plans for other gas cooled stations, particularly in Germany, have not even reached the negotiating stage. Business potential for a brand new plant designed to manufacture the Calder Hall type element, therefore, is not very promising. There is an additional problem: if a Euratom subsidy is forthcoming, it would be on the basis of an exchange of information and personnel with other Common Market companies. Pressure would be brought to bear on the company concerned to pass on the 'know how' gained to the other five members of the Common Market, and this, understandably, is a stumbling block. Not that this problem is insuperable, however, for there have been instances of firms receiving Euratom research contracts (e.g. under the Euratom-US scheme) refusing to part with all their information.

French competition

The alternative then is to extend the facilities already existing in the Common Market countries; this points principally to France — to the Société Industrielle de Combustible (SICN) at Annecy who so far have been responsible for the fuel elements of most of the French reactors. An additional plant is going up at St. Lobes in the Gironde that will have an estimated output of 250 tons by 1962 and of 400 tons by 1964 — but the fuel elements to be produced are for heavy water reactors. Another possibility is the German firm of NUKEM who have already produced natural and enriched uranium elements, but their output so far is relatively small and a lot more experience is required to compete on a scale comparable with the French company.

Another question is raised: who in Europe can process irradiated fuel elements? The only effective plant at the moment is also French — that of Saint-Gobain, operating at Marcoule. The Eurochemic project is getting under way. In addition to this, plans for a reprocessing and refabrication pilot plant have been announced by the Italina CNEN for completion by mid-1963.

In spite of the trends towards European self-sufficiency, the UK could stay in the running for export business if it really wanted to: after all it has considerable experience behind it. What is primarily needed is a positive lead from the Government to join the Common Market; if the UKAEA really wants a big finger in the European pie then Sir Roger Makins is the man to convince the policy makers of the necessity.

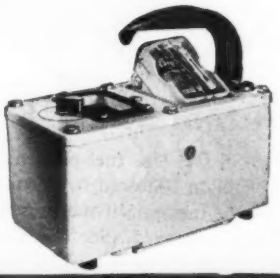
EKCO

Reactor Health Instruments

The four instruments illustrated here are from the Ekco range of health instruments that are providing accurate, reliable radiation measurement in the nuclear field.

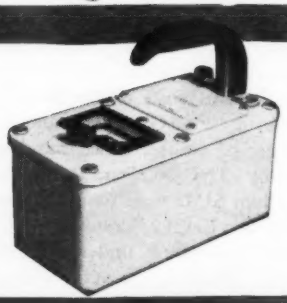
EKCO TYPE N555 RADIATION MONITOR

This ionisation-chamber type radiation monitor provides rapid, accurate measurement of gamma and high-energy X-ray dose-rate.
THREE RANGES: *0-1,500 mr/hr., 0-150 mr/hr., 0-15 mr/hr.*
ENERGY DEPENDANCE (*Gamma*)—*Within 2.5% between 350 KeV and 3 MeV.*



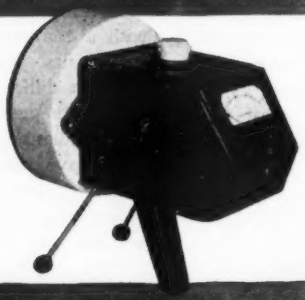
EKCO TYPE N578 SLOW NEUTRON SURVEY METER

The N578 is designed for the measurement of the dose-rate from slow neutrons in the energy range from 0.025eV to 30eV approx.
RANGES: *0-150 mrem/hr., 0-15 mrem/hr.*



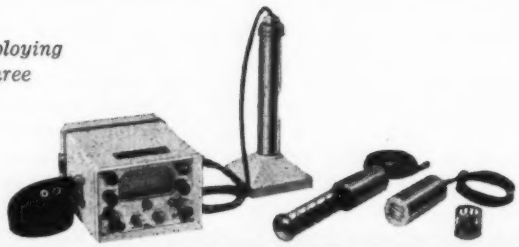
EKCO TYPE N596B RADIATION MONITOR

Portable, battery-operated ionisation chamber instrument, designed to give equal response to beta and gamma rays and calibrated in millirads/hour for beta and gamma. This instrument CANNOT FOLD-BACK IN A VERY HIGH GAMMA FLUX. RANGES: *0-3 mrad/hr. 0-30 mrad/hr., 0-300 mrad/hr. Integrating range 0-30 mrad with a time constant of 15 hrs.*



EKCO TYPE N645 FIELD RATEMETER

A transistorised battery-powered portable ratemeter, employing printed circuit technique, providing three ranges with three integrating time constants. The head units (available separately) are in general sensitive enough to measure the appropriate tolerance doses of ingestible alpha, beta or gamma contamination. RANGES: *0-10 c.p.s., 0-100 c.p.s., 0-1,000 c.p.s.*



EKCO

Full details of the complete range of Ekco Electronics Reactor Health Instruments will gladly be provided on request

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WPS—358

WORLDVIEW

the month in atomic energy

EUROPE

The Six: move to make Latina fuel

Brussels A proposal to subsidize the manufacture of fuel elements for the threeEuratom nuclear power station projects is to go before the Council of Ministers, the Euratom Commission's governing body—probably at its meeting on June 26-27. The proposal has met with French opposition and some objections from Germany, and a Brussels source told *Nuclear Power* that it was by no means certain that it would be successful.

Basically, the philosophy behind the subsidy is that as the making of the initial fuel charges would be valuable experience, Common Market firms undertaking this should qualify for a research grant. This would be conditional on their making the results of their experience known to Euratom. Funds would also be provided to cover costs during the initial start-up period of the reactors.

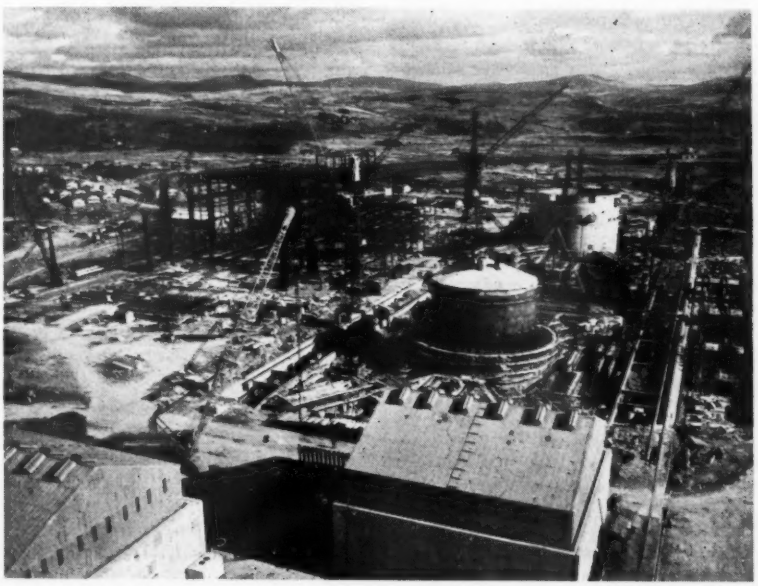
The initial approach for aid came from the operators of the three stations; it was suggested that help should be given, to the tune of $19 million, for (*a*) fuel element manufacture; (*b*) the supply of fissile material and (*c*) the initial cost of putting the reactors into operation. Discussions on this took place at a recent meeting of representatives of Euratom and the European Community's European Electric Producers' Organisation.

The Euratom Commission has issued no official statement on the proposal but a *Nuclear Power* source in Brussels said the specific proposals were: (1) SIMEA (Società Italiana Meridionale Energia Atomica), operators of the 200 MW Latina station: 50% of the cost of fabrication of fuel elements made in the Community up to a total of $3 million. This figure relates only to the initial charge and will be raised to $4 million should the refining of the uranium be carried out in Common Market countries. (2) SENN (Società Elettronucleare Nazionale), operators of the 150 MW BWR at Punta Fiume: $3 million to cover the deficit in operations during the start-up period and $4 million towards the manufacture of fuel elements. (3) SENA (Société d'Energia Nucleaire Franco-Belge des Ardennes), operating company for the proposed 242 MW PWR at Chooz: $5 million towards the cost of fuel elements and $3 million to underwrite costs during the start-up period.

In return, there would be an exchange of information on the making of the fuel elements with Euratom and also an exchange of personnel. It is also understood that the fuel element subsidy would be for the initial charge only.

Of these three stations, Latina is the only one that is British-built and it has always been AEA policy that British-built reactors should be fuelled with British-designed fuel. This does not exclude the possibility of the fuel elements being manufactured on the Continent under an access agreement signed with the UKAEA. In fact, the Sixth Annual Report of the AEA stated that negotiations were proceeding with foreign organisations regarding the possible grant of licences by the Authority for the manufacture overseas of natural uranium fuel elements by the Springfields process.

Fuelling arrangements for Latina, meanwhile, are likely to be further delayed because of the subsidy proposal. It would, for instance, have been reasonable for an agreement on the fuel for this station to be signed last summer. As it is, despite a tentative approach for tenders some months ago, no steps have been taken. Here, incidentally, the AEA price was not the lowest but *Nuclear Power* understands that no other offers matched the Authority's guarantees or buy-back price.



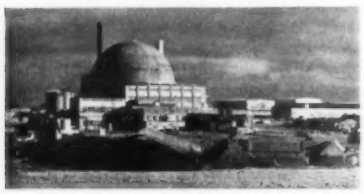
TRAWSFYNYDD PROGRESS A general view of the site of the 500 MW station under construction at Trawsfynydd, North Wales, showing the two reactors being built. The designer and main contractor is Atomic Power Constructions

WORLDVIEW

The AEA solves Dounreay entrainment problem

London. AEA scientists and engineers have now established the causes of the gas entrainment problem at the Dounreay Fast Reactor; steps are being taken to prevent this behaviour.

The trouble was noticed during the first physics experiments in the Dounreay programme when small changes in reactivity were observed. These were found to be due to bubbles of nitrogen



The Dounreay Fast Reactor

becoming entrained in the sodium/potassium coolant passing through the core. According to the AEA, gas entrainment is a serious problem not only because of the reactivity changes which result but because under power conditions, the heat transfer properties of the coolant would be impaired, leading to local hot-spots which could, in turn, bring about melting of the fuel.

Preliminary tests indicated that one cause of the trouble was the liquid metal expansion tanks above the primary circuits. A reduction in the level of liquid metal in these tanks was found to be allowing gas to pass down a pipe normally filled with liquid metal. Further experiments showed that other possible trouble sources existed.

The main causes were eventually established as: 1. The emptying of expansion tanks; 2. The pressure drop occuring at certain coolant flow rates in the vertical tubes which form part of the control rod mechanisms causing nitrogen to be drawn down the tubes into the main circuit and 3. A similar effect occuring in the instrument thermocouple tubes which lead down into the core.

The tank emptying effect was found to be due to the blocking of certain small pipes and the AEA say these are being cleared. Modifications are being made to the control rod and thermocouple tubes to alter their hydraulic characteristics by providing relief holes and baffles.

At the end of this work, the programme for raising the reactor power will be reviewed. So far, the reactor has been operating at low powers (up to 1·4 MW). The results, add the AEA, 'have been most encouraging and the forecasts made from the original work at Harwell and Risley have proved to be accurate and well founded'.

Chemical processing of the first Dounreay Fast Reactor charge has been successfully carried out and this has proved the satisfactory operating characteristics of the processing plant. Chemical development work is needed for the production and processing of the new types of fast reactor fuels and this work is continuing, the AEA adds.

Mitchell's carry out Italian BWR study

London A reactor design study to tie in its output with steam conditions that already exist is being prepared by Mitchell Engineering Ltd. for the Italian utility company, Larderello. The reactor system being considered is a boiling water type of 25-30 MW.

Completion of the study is expected within six weeks with the decision to build to be made by August.

The design study contract award was made in December, 1960, and called for the design of a nuclear power plant to tie in with existing geothermal steam electrical facilities at Larderello, Tuscany. The amount of thermal steam from the area is reported to be falling and in order to maintain the facilities, the Italian company has been considering other means of steam generation.

The reactor system will have a thermal output of 110 MW and incorporate a closed cycle heat transfer system under which steam is produced at pressure and temperature conditions suitable for feeding to the existing plant. Mitchell's are working together with AMF Atomics on the project through Mitchell Italia SpA and AMF Italia.

Soviet team visits UK

London Professor V. S. Emelyanov, Director of the USSR Main Administration for the Utilisation of Atomic Energy, headed a Russian team which visited the UK in the week beginning May 14. They discussed arrangements for further collaboration in the peaceful uses of atomic energy and visited AEA nuclear establishments.

• **Switzerland** A new national grouping, Nationale Gesellschaft zur Forderung der Atom-Technik (NGA), has now been formed and will proceed with building an experimental nuclear power station at Lucens in corporating a reactor originally developed by Sulzer for Thermaton AG.

• **IAEA** New research findings on the biological effects of radiation were reported at a recent Vienna meeting of 28 radiobiologists from 15 countries.

• **United Kingdom** The public inquiry into the CEGB's proposal to build the Wylfa, Anglesey, nuclear power station will be held in Amlwch, Anglesey, on May 30.

Spanish nuclear plans progress

Madrid CENSUA (Centrales Nucleares S.A.) has formally applied for official permission to build a 250 MW nuclear power station by the Tagus River, some 80 kilometres south of Madrid. This is the second such application made this year by a Spanish concern. NUCLENO (Centrales Nucleares del Norte S.A.) applied earlier in the year for permission to build a similar sized plant at Santa Maria de Garona in Northern Spain.

The high cost of research

London The high cost of nuclear research and development was causing some apprehension that this expense might not be recovered by sufficiently frequent orders, Mr E. M. Price, managing director of English Electric Construction Ltd, stated recently.

Mr Price said that more than £1 million had been spent on facilities at the Whetstone testing and research centre of the English Electric-Babcock and Wilcox-Taylor Woodrow Atomic Power Group. In addition, running costs amounted to over £2 million a year. Orders for nuclear power stations worked out at one power station for each group every three years. This meant that £6 million costs had to be recovered on each order—if there were only British orders. The present rate was barely sufficient to keep the group going but he hoped there would be occasional overseas orders. The group was, itself, tendering for the Indian contract for a nuclear power station.

• **France** A guidance note on general technical conditions for nuclear ships has been submitted to the Nuclear Energy Commission of the Comite Technique Naval du Bureau Veritas.

• **W. Germany** The Atomic Energy Commission has asked the Federal Government for more intensive support for nuclear research and technology. A sum of 500 million D-marks annually was needed—an increase of 300 million D-marks over the present sum.

First Halden fuel experiments succeed

Oslo The first experiments with the initial fuel charge for the Halden reactor have been successfully completed. Work is now going on in the experimental boiling heavy water reactor, to accommodate the second fuel charge, increase the output and expand experimental facilities.

After the second fuel charge is installed by the end of this year, the reactor will be brought up to 20 MW. Later in 1962, it will be connected to the steam distribution system of the paper factory Saugbrugsforeningen on whose premises the reactor is located.

During the experimental period with the first fuel charge, the reactor was operated at powers up to 6 MW and temperatures up to 155° C. It was carried out in two stages. The first was low power operation and the second was at the full power level designed for the first fuel charge. The preliminary results of the experimental operation was presented to a group of representatives from the participating OEEC countries on May 2.

The Halden reactor, a European Nuclear Energy Agency project, went critical on June 29, 1959, and produced steam for the first time on October 5, 1960. It is operated jointly by 14 nations under an OEEC agreement.

• **Euratom** The Ispra (Italy) Nuclear Research Centre has been formally transferred to Euratom in accordance with the agreement signed between Euratom and the Italian Government.

• **Italy** Yugoslav technicians are expected to work on a proposed Italian 30 MWt OMR together with Italian scientists under a recent technical co-operation agreement signed between the two countries.

• **United Kingdom** A revised route for a 400 kV supergrid line from Sizewell nuclear power station is being planned to preserve more of the landscape.

• **Poland** The country's third reactor, of about 1MW, is to be built during the present Five Year Plan. It will be used for fundamental physics research.

Bradwell cost is £58 million

London Full operation of the 300 MW Bradwell nuclear power station is expected by the middle of 1962. The cost of construction, including road widening, land purchase, compensation for the erection of pylons and the nuclear fuel charge was likely to be £58 million, the House of Commons was told by Mr. J. George, the Parliamentary Secretary, Minister of Power.

He added that nuclear generated electricity could become competitive with conventionally produced electricity in about seven years' time if interest rates were to drop to 3%. The present interest rate assumed in estimating future costs was 5½%.

German group asks for OMR design study

Bonn Preliminary design work on 150 MW organic moderated and cooled reactor for the Baden Wurttemberg Nuclear Power Plant Planning Association (KBWP) is to be undertaken by Atomics International of the US. Interatom, AI's German affiliate, is expected to assist in the preliminary design work. This is expected to take about 13 months and provide the basis for subsequent final engineering and construction should KBWP decide to proceed with construction. The KBWP group selected the OMR after an evaluation of competing proposals on other types made by US and UK companies.

The project may come under the US-Euratom programme for which proposals for 1965 completion were reviewed in March by the Euratom Council of Ministers. Only one other group is still interested in this programme the Franco-Belgian SENA group which is planning to build a 242 MW PWR at Chooz.

The KBWP group was formerly the AKS group of companies.

Labour troubles delay AGR building

London Labour difficulties have hampered the building of both the Advanced Gas-Cooled Reactor and HERO, the zero energy facility alongside the AGR, reports the Atomic Energy Authority.

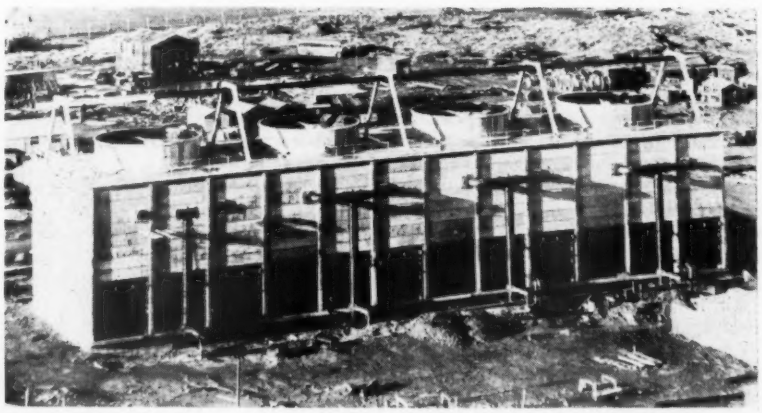
Despite these troubles, the AGR construction is scheduled to be completed in July and the reactor is to be handed over to operations staff for fuel loading in the late autumn. HERO'S handover is also expected to be in the autumn of this year.

This admission by the AEA of labour strife spotlights the difficulties besetting most nuclear power plants being built in the UK—troubles at Hunsterton being a prime example.

On AGR progress, the AEA say that inside the reactor vessel, the graphite core and its supports are complete and the neutron shields have been erected. The can failure detection pipes are being fitted and connected. One gas circulator has been successfully tested on a heat exchanger at design conditions of temperature and pressure and is now undergoing minor modifications. A second machine has been delivered and continuous running tests are under way.

In addition, uranium oxide pellets and components for the AGR stainless steel canned fuel elements are in production and an assembly plant is due for commissioning.

In spite of difficulties with beryllium production, and the corrosion problems which have arisen, a quantity of beryllium-canned elements are being manufactured. It is planned that up to 20% of the first charge will be beryllium-canned.



AGR NEARS COMPLETION The four cooling towers for the AGR which itself is due for completion in July despite labour troubles

WORLDVIEW

Work starts on Sizewell station

London Construction work on the 580MW Sizewell nuclear power station began on April 4 when site preparation work started. The £55 million station is due for 1966 completion by the English Electric, Babcock & Wilcox, Taylor Woodrow atomic power group.

Responsible for the building and civil engineering work is Taylor Woodrow Constructions Ltd and it is expected that by the beginning of July, detailed excavation of the reactor foundations will be well advanced. The total labour force will rise to a peak of about 2400 in 1962. Babcock & Wilcox Ltd are building the two 63½ ft diameter pressure vessels, eight 91½ ft high and 22½ ft diameter boilers and all the ancillary coolant gas ducting and steam piping. The English Electric Company will be responsible for the nuclear and electrical engineering with the turbo-generators being made at its Rugby works and the nuclear components at Whetstone.

Government agrees to three university reactors

London The Government has at long last approved — in principle — the provision of three reactors which will be available to the universities and colleges of technology for teaching and research.

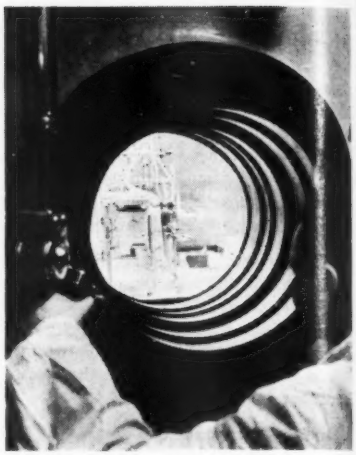
Announcing this in the House of Commons, Mr. Denzil Freeth, Parliamentary Secretary for Science, said that one reactor would be sited in Scotland and the other in Lancashire. It was proposed to site the third in the London area. It would be available to the Imperial College as well as other institutions in London. Negotiations on arrangements were continuing, he added.

The firms able to make research reactors in the UK are the GEC (CONSORT), Vickers (TRIGA) and Pye (AMF reactors). The JASON reactor is made by the Hawker Siddeley Nuclear Power Company who, however, are closing their Langley works.

Design changes on Hunterston fuel elements ?

London Tests are still being carried out to determine the fuel elements for the 328 MW Hunterston nuclear power station being built by the GEC-Simon Carves Group. According to an Atomic Energy Authority spokesman, production of these fuel elements is not due to start until the end of this year. The time in between is being used for endurance tests and tests for possible changes in the heat transfer surface. No final decision on the fuel element design will be taken until these tests have been carried out, the AEA added.

• **Italy** The RC-1 (TRIGA Mark II) reactor at the Casaccia Nuclear Centre, near Rome, is undergoing modifications and has been shut down since January 20. It is expected to resume operations soon with expanded research capabilities.



POLISH HOT CHAMBER Seen at the Institute of Nuclear Research, Swierk, Poland, is the hot chamber associated with the Soviet-designed reactor EWA. The Institute itself is the most recent Polish scientific establishment but has already made a name for itself in the nuclear field

OVERSEAS

The G.E.C. proposes French graphite for Tokai-mura

Tokyo French graphite is now proposed as the moderator for the Calder-type Tokai-mura 150 MW reactor, according to the Japan Atomic Power Company (JAPCO). Reason for the change from the originally selected British-made graphite is that the French material is reported to have greater tensile strength.

The initial suggestion, says an announcement by JAPCO, came from the General Electric Company who early this year suggested that the graphite should be obtained from Pechiney of France. These proposals were discussed early in March and it was agreed to alter the specifications subject to the following conditions : (*a*) that experimental data on the nuclear properties and the strength of the Pechiney graphite was provided and (*b*) that the price should not be increased.

Dr T. Ipponmatsu, vice-president of JAPCO, told the Japanese Parliament when questions were raised on the matter, that the change was an improvement in design which would increase the reactor's safety and reliability.

It has also been reported widely in Japan that cracks in test plates for the pressure vessel had been found and that the materials did not meet the Japan Industrial Standard. This was due to a difference in Lloyds and Japanese standards. It was probable that completion of the reactor would be delayed as a result, the reports added.

• **United Kingdom** Uranium drilling operations in Kirkcudbrightshire, Scotland, have been completed. No further work is to be undertaken by the Atomic Energy Division of the Geological Survey as the overall content of uranium ore is too small to warrant further tests at the present time.

• **United Kingdom** An increase of more than 25 per cent over design figures for electricity output will soon be achieved at Calder Hall and Chapelcross. It has been made possible without extra fuel cost.

• **Australia** MOATA Australia's second research reactor, went critical recently. This 10 kWt reactor cost £65,000 and was ordered from Advanced Technology Laboratories, California.

• **Canada** Talks on the UK-Canadian Letter of intent to purchase 12,000 tons of Canadian uranium will open on June 12 in Ottawa, the Trade Minister, Mr. George Hees announced recently.

• **Indonesia** The US is contributing $350,000 towards the cost of the TRIGA-II 100 kW training reactor being built at Bandung as part of a centre which includes laboratories, an electronic shop and other supporting facilities.

• **USSR** A National Board for the co-ordination of scientific research has been formed. The president is Mikhail Khrunitschev, who is head of the State Planning Authority.

International nuclear energy spending rises

Washington More than $350 million (£125 million approx.) is the figure for appropriations and expenditure on atomic energy for 1956-64 for nearly 20 countries, according to figures issued by the Business and Defense Services Administration (BDSA) US Department of Commerce.

The total is based on figures obtained from Foreign Service Offices. In addition, West German recommendations show an increase of $200 million and the Department quotes industry sources as reporting that Japan is buying a British nuclear power station costing $56 million while France is contemplating an expenditure of $253 million this year. Overall, the potential expenditure is nearly $1000 million and the Division points out that there may be other expenditures being considered which have not yet been made public.

Based on statistics so far obtained from Foreign Service Offices, BDSA's Power Equipment Division lists the following projected appropriations and expenditures covering the years 1958 to 1962:

	1958	1959	1960	1961	1962
		(In thousands of US dollars)			
ARGENTINA	200	240	240	330	370
COLOMBIA	—	—	—	224	—
DENMARK*	7906	7748	7229	7968	7521
EGYPT*	1304	915	1136	1741	—
FINLAND	31	219	906	219	—
INDIA*	—	14,598	19,559	22,848	—
ITALY*	—	25,120	8000	32,000	40,000
LEBANON	—	—	—	64	—
NORWAY*	—	2270	2429	1723	3591
PAKISTAN*	140	336	840	3788	—
PORTUGAL	1890	1224	1427	—	—
SPAIN	6976	6976	5500	5500	—
TURKEY	133	1333	1777	—	—
UNION OF SOUTH AFRICA	—	11,200	For 5-year Programme		—
VENEZUELA*	—	4342	4427	4886	—
YEARLY TOTAL	18,580	76,521	53,470	81,291	51,482

*Denotes Fiscal Year

Pakistan plans three nuclear power stations

Karachi Steps to have Pakistan's first nuclear power station operating in 1965 are now being taken. According to Dr I. H. Usmani, chairman of the Pakistan Atomic Energy Commission, the Internuclear Company of Missouri is undertaking a survey of the country and is preparing plans for three nuclear power stations.

A preliminary report from Internuclear is to be submitted this month (June) and a final report in August. Present proposals, Dr Usmani said, were for the stations, each having a minimum capacity of 100 MW, to be located in Karachi, Lyallpur in West Pakistan, and at Chittagong in East Pakistan.

It is understood that negotiations are under way with the World Bank for finance for these three stations but this will be dependent on the feasibility study being carried out by the three-man team from Internuclear and Gibbs & Hill Inc. of the USA.

Meanwhile, in preparation for the stations, the Pakistan AEC has completed plans for setting up a nuclear institute at Islamabad and for opening two training and research laboratories at Lahore and Dacca Universities. A total of 80 scientists were being sent abroad this year to receive training in nuclear science and it is hoped to have 400 trained in the next five years.

Pakistan's Ambassador to the United States, Mr Aziz Ahmed, examines the control console of an AMF research reactor at Industrial Reactor Laboratories, Plainsboro, New Jersey. AMF has developed a master plan for a complete nuclear research centre at Rawalpindi which will include a 5 MIW pool type reactor

Soviet research centre enlarges facilities

Moscow Main work of the Central Asian nuclear research centre, near Tashkent Ulugbek, is at present devoted to the application of radioisotopes, according to a Soviet newspaper report. Production of a gamma-consistometer, designed by the Institute, has already started. This device is used for measuring the density of pulp, liquids and powdery substances. Other measuring devices are being developed.

The centre is equipped with the first Soviet research reactor to be built in Central Asia and further facilities will include a nuclear physics laboratory and a cyclotron.

Research projects in hand include a new method of processing silk cocoons with the aid of gamma radiation devices and experiments to extend the life of useful plants and bacteria.

• **South Africa** About £181,000 of the £500,000 needed for a nuclear research institute for the Universities of Cape Town and Stellenbosch has been raised by donation.

• **United States** NAP-100, a lightweight nuclear generator which converts electricity directly into electricity, is undergoing performance testing, say the makers, Westinghouse. The 10 in high, 16 in diameter generator is designed to use radioactive isotopes as its heat source.

• **United States** Complete proposals for a 375 MW PWR have been filed with the AEC by Southern California Edison and Westinghouse. Initial negotiations for the $78 million station were made a year ago.

• **United States** An increase in containment time for rapidly-circulating hydrogen ions at moderate densities in a magnetic field, from a few thousandths of a second to about three seconds, has been reported by Oak Ridge National Laboratory fusion scientist C. F. Barnett.

• **Japan** The Atomic Energy Commission has issued its fourth annual report in which it says that the nation's first uranium concentrate of kilogram quantity obtained from domestic ores was produced during the year.

WORLDVIEW

Symposium stresses uranium carbide uses

Washington Discussion at the recent symposium on uranium carbides as reactor fuel materials held at Germantown, by the AEC, centred on the application to reactors, preparation and fabrication and irradiation data.

Summarizing the meeting, Mr J. Connor, Fuels and Materials Branch, AEC Division of Reactor Development, said: '. . . we have heard that because of three prime properties—high thermal conductivity, high uranium density and high melting point and temperature stability—the use of this material in high temperature power reactors of the future is extremely likely. Although the material's limitations as a nuclear fuel have not been fully defined, it would appear that in certain types of reactors, the unique characteristics of uranium carbide can and will be advantageously utilized'.

Next year, he added, would see a shift in emphasis from the preparation and fabrication of uranium carbide to comprehensive property determination, both out-of-pile and in-pile. Physical and mechanical properties, as a function of temperature, would receive added emphasis. Other work would deal with alloying additions to improve compatabilities, strength and/or corrosion resistance. Work on alloying additions to improve atmospheric handling was likely to expand.

• **W. Indies** Studies will start in the summer near Bermuda to study the distribution of radioisotopes by ocean currents says the USAEC

• **Pakistan** An agreement has been signed with a US firm for setting up a Pakistan Institute of Nuclear Science and Technology.

• **United States** The AEC has authorised Commonwealth Edison to resume limited operation of the Dresden nuclear power plant which has been shut down since November, 1959, because of faults in the control rod drive mechanism. (See *Worldview*, May, p 58).

• **United States** The AEC has ordered the University of Wyoming to close down its L-77 solution type, light-water moderated reactor. During a Commission inspection, the inspector observed that the reactor was operating but was not attended by a licensed operator.

US sends fuel for Turkish research reactor

Ankara Natural uranium fuel for the Physics Department of the University of Ankara is to be shipped from the United States under the terms of the US-Turkish agreement on co-operation in the peaceful uses of nuclear energy. The cost of the 5500 kilograms of fuel is estimated at $100,000. A 1MW AMF swimming pool reactor is being built in Turkey.

India revises fuel needs

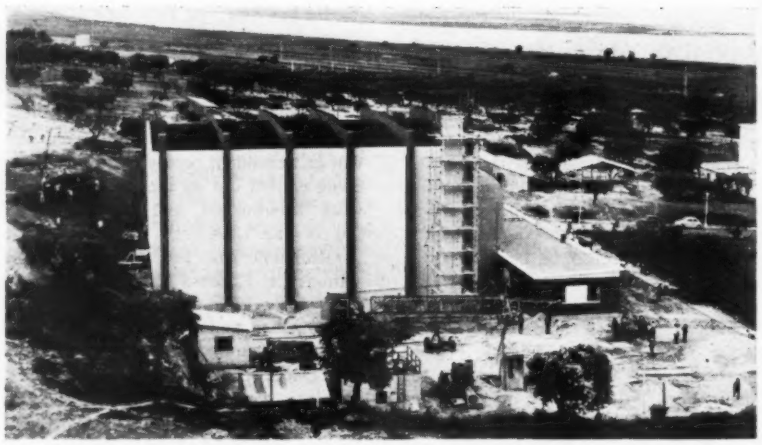
New Delhi To meet fuel needs of the proposed 300 MW nuclear power station to be built at Tarapore, the capacity of uranium metal plant and fuel fabrication facility at Trombay is to be increased 400%. This expansion scheme will cost about £1,875,000 and is included in India's Third Five-Year Plan.

Other proposals include the setting up of a plant to treat irradiated fuel elements and to extract by-products. This is to be commissioned in 1962-63.

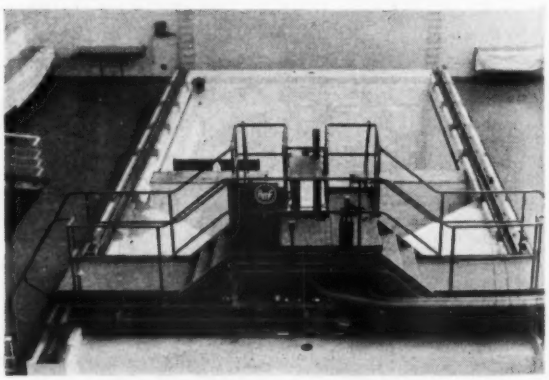
Primary uranium production will also be increased and the Jaduguda Mines, the main source of uranium in India, will be developed fully at a cost of over £3 million. To cope with the increased flow of ore, an ore mill with an eventual capacity of 1000 tons daily is to be built within three years.

Study suggests AEC changes

Washington A major revision of the AEC's regulatory programme is proposed in a report by the Joint Committee of Atomic Energy staff. This recommends that a three-man Atomic Safety and Licensing Board be set up in the AEC. The members would be appointed by the President and confirmed by the Senate and would have final licensing authority and an active part developing regulatory standards and rules for reactors. The Board would review all proposed government-owned and privately-owned reactors with hearings to be compulsory before it for construction permits. It would also control the issue of specific and general materials licenses.



PORTUGUESE REACTOR This 1 MW research reactor at Sacavem, seven kilometres north-east of Lisbon, was inuaugurated recently and is part of the facilities of the Junta de Energia Nuclear. Construction of the reactor was completed within 18 months



The interior of the ▶ research reactor with the bridge that spans the top of the pool. It is the 15th that AMF has placed into operation

Japan's second power reactor

Tokyo Two years have been allowed for preparation for Japan's second nuclear power station, according to the Japan Atomic Power Company. This will probably be installed in western Japan (see *Worldview* March p 56).

The company stated that the reactor would probably be a light-water cooled type generating 200-250 MW. Part of the funds for this reactor would be raised abroad. The reactor type would probably be chosen from the US General Electric's BWR, Westinghouse's PWR at Dresden or the Yankee plant in Massachusetts, the company added. No indication was given of when a team would go to the USA to make a preliminary survey of these types with particular reference to operating records.

The choice of site is expected to be difficult though the company has decided broadly to situate it in the western part of Honshu Island. However, no such readily available site such as at Tokai Mura exists and detailed studies will have to be made.

Canadian heavy water plans

Ottawa A study into the economics of Canadian production of heavy water is being undertaken by the Research and Development Division of the Eldorado Mining and Refining Company. The president of the Crown-owned company told the Canadian House of Commons Research Committee that Eldorado was also studying the probable demand for both natural and enriched uranium. Other aspects of the company's research programme included research into non-nuclear uses of uranium, including its use as an alloy in steel.

Production of heavy water in Canada was abandoned after the war when it was found cheaper to buy the amounts needed for research from the United States. The former plant was situated at Strail, British Columbia.

Savannah Hearing ends

Washington The recent AEC hearing to consider the nuclear safety aspects of the *N. S. Savannah* went through without incident. There was virtually no opposition to the ship's nuclear propulsion system being operated The results have been submitted to the Commission which will decide whether to authorize the start-up of the reactor and its trials.

A point that arose was that the stress corrosion cracking problems encountered with stainless steel components in the Dresden reactor might require modifying similar components in the *Savannah*.

The *Savannah* is undergoing non-nuclear tests at the moment. She is virtually complete and the date of her sea trials is expected to be announced shortly. A contract for the vessel was awarded in 1957 to Babcock & Wilcox for development and fabrication of the 74 MW PWR and also one for building the ship, to the New York Shipbuilding Corporation. The operator is to be the States Marine Lines.

• **United States** The state of Rhode Island has bought a 30 MWt open pool research reactor from the GE Company for 1962 operation.

• **United States** Major construction work has started on the 60 MW BWR to be built for Pacific Gas and Electric at Humboldt Bay, California.

• **Australia** Growing interest in the industrial uses of radioisotopes is being shown in Queensland, according to the Minister for National Development, Senator Spooner.

• **United States** Columbia University is to buy a TRIGA Mark II research reactor.

• **United States** A successful 500-hour testing programme at 110 MW has been completed at Yankee Atomic Electric Company's PWR at Rowe, Massachusetts.

Atomics International orders Hallam fuel

New York Atomics International has placed an order for about two tons of 3·7% enriched uranium carbide with the Spencer Chemical Company. It is thought that the material will be used for prototype fuel elements for the 75 MW Hallam sodium graphite reactor being built by AI in Nebraska. The reactor is scheduled for early 1962 completion.

AEC issues new Costs Manual

Washington A ' new bible ' for economists, at least until the IAEA issues its manual on costs, has been released by the USAEC. Entitled ' Costs of Nuclear Power ', this report is a revised version of an earlier edition published in July, 1959. It deals with plants in operation, being built or being designed for construction at an early date.

Several new reactor projects are included in the present report (compared to the previous) and a breakdown into major components is given of the capital cost of US and foreign nuclear power plants—the report cites 30 overseas plants in addition to 22 in the US. An attempt is also made to consider power costs on the basis of consistent definition and assumptions for the various nuclear power plants and for comparable fossil fuel plants.

While restating that nuclear power must depend primarily on reductions in costs resulting from research, development, engineering and production activities to become economically competitive with power from fossil fuels in the next decade (as against becoming competitive because of an increase in fossil fuel prices), the report also carries two particularly useful tables. One gives the reported costs of constructing specific nuclear power plants and the other, the design values of efficiency and steam conditions for given nuclear plants.

Two other reports of interest in the cost field have recently been issued. The first comes from the AEC, through the Department of Commerce, setting out a complete guide for planning, setting-up, and operating nuclear power plants which are to have superheaters of such fossil fuels as coal, oil and gas. The other, from the Shell International Petroleum Company Ltd, deals with the economics of small power reactors with special regard to the needs of less-developed countries. This useful study reiterates that over the next 15 years, small stations (up to 100 MW) are unlikely to become generally competitive with conventional plant under the conditions which exist in less-developed countries.

	Capacity, net MWe	Total cost ($ million)	Costs $ net kWe
Gas-cooled			
AVR (W. Ger.)	15	9·5	630
EGCR	22·3	30·6	1370
AGR	27·3	24·6	900
EDF-1	60	33	550
Berkeley	137·5×2	123	450
Bradwell	150×2	134	450
Hunterston	150×2	115	380
JAPC (Japan)	158	85·6	540
EDF-2	170	59	340
Latina	200	73	370
Hinkley Point	250×2	186	370
Trawsfynydd	250×2	172	340
Dungeness	275×2	169	310
Sizewell	290×2	154	270
EDF-3	300	140	350

(A selection from Table 4, ' Costs of Nuclear Power ')

' Costs of Nuclear Power ', (TID-8531), USAEC, Office of Technical Information, price 50 cts. Available from Office of Technical Services, US Department of Commerce, Washington 25.

' An Evaluation of Fossil Superheat for Nuclear Power Plant ', 297 pp, price §3.50. Available from Office of Technical Services, Business and Defense Services Administration, US Department of Commerce, Washington 25.

Nuclear Reactors No. 5. ' The Economics of small nuclear power stations.' Shell International Petroleum Company, Economics Division, Great St. Helen's London, EC3.

WORLDVIEW

PM-1 REACTOR A full-scale model of a two-year loading for the PM-1 1 MW reactor is examined by two Air Force technicians. This US optimized, portable pressurized water reactor will be installed and tested in Wyoming and was developed under the Army nuclear power programme

SL-1 reactor to be decontaminated

Washington Plans for decontaminating and dismantling the 3 MW SL-1 reactor have been submitted to the AEC. Before any steps are taken, however, the AEC will consult the Ad Hoc Advisory Committee appointed to consider the future use or disposition of the SL-1. The SL-1 (Stationary Low Power Reactor No. 1) has not been in operation since January 3 when an accident resulted in the death of three persons. (See NUCLEAR POWER, March, p 96 and February, p 59).

Meanwhile, the Ad Hoc Committee has reviewed data which has become available since its initial report on January 12. It also examined a report from Combustion Engineering Inc, operating contractor for the SL-1, that there was little or no water in the reactor vessel. This report was made after the introduction of two probes into the reactor vessel in April. (Without water in the SL-1 core to moderate neutrons, another criticality cannot occur). The absence of water is contrary to an earlier assumption based on studies of motion pictures of the inside of the reactor vessel.

Entry into the reactor building has been prohibited pending determination of the reactor's status. Present radiation readings in the reactor room range from 30 roentgens per hour to less than 200 roentgens per hour. Readings immediately after the accident ranges from 50 to 100 roentgens per hour. The high readings were over the top of the reactor.

• **United States** Construction has been started on waste disposal facilities for the Saxton Nuclear Experimental Corporation's 5 MW PWR at Saxton, Pennsylvania.

• **Japan** The Atomic Industrial Forum and the US Atomic Industrial Forum are to hold a joint conference in Tokyo from December 5-8.

• **United States** The ML-1 (Mobile Low Power Prototype Reactor) is undergoing pre-startup testing at the National Reactor Testing Station. ML-1 is a direct cycle gas cooled system designed to produce 330 kWe.

• **United States** Michigan Chemical Corporation is purchasing 100 tons of Malayan monazite from the UKAEA.

• **South Africa** The pilot plant for producing uranium metals and salts, which went into operation in November 1960, was officially opened in April.

• **United States** The number of workers at AEC plants injured during 1960 was the lowest on record, according to Mr A. R. Luedecke, AEC General Manager.

• **Australia** The Government has decided to accept a favourable tender for the mining of the newly discovered uranium orebody at Rum Jungle Creek South, Northern Territory.

• **United States** A provisional AEC operating license has been issued to the National Aeronautics and Space Administration for its 60 MWt light water cooled and moderated research reactor at Plum Brook.

Japanese give details of ore-carrier

Tokyo Further details of the study of a nuclear ore-carrier made by the Nippon Nuclear Ore-Carrier Joint Study Group (see *Worldview*, February, p 57) bring out more of the design features of the vessel and its indirect cycle boiling water reactor.

PRINCIPAL CHARACTERISTICS

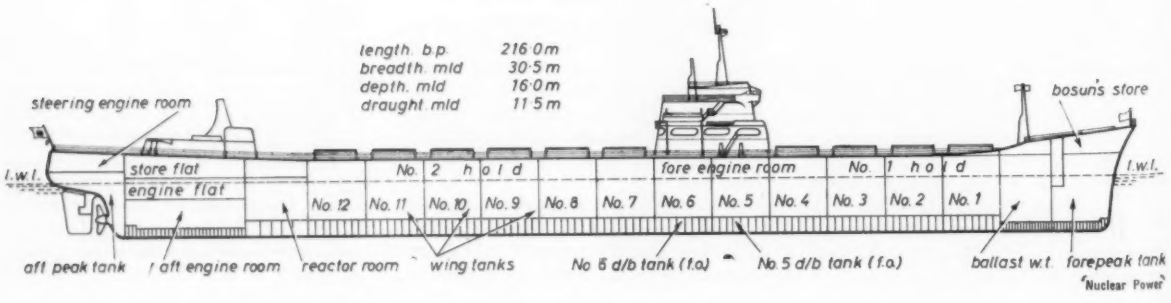
Length overall	747·84 ft
Length B.P.	708·48 ft
Moulded breadth	100·04 ft
Moulded depth	52·48 ft
Designed draught	37·72 ft
Gross tonnage	30,000 tons
Deadweight tonnage	46,000
Ore hold capacity	25,884 m
Max. speed, full load	18 knots

REACTOR DETAILS

Output	63 MWt
Fuel	116 kg U 235 (2·35%)
Core	cylindrical prism, 54·5 in diameter, 44·9 in high with 104 fuel assemblies
Elements	neutron flux (th. av.) $2{\cdot}45 \times 10^{13}$ n/cm² sec
Burn-up	11,700 MWdt
Pressure vessel	Carbon steel, stainless steel clad. 16·3 ft high; inside diameter 6·3 ft thickness 3 in; design pressure 1150 psia

The ship examined by the Study Group was a 46,000 dwt, 22,000 shp carrier powered by a 63 MWt BWR. Choice of the carrier over a tanker was because: other tanker studies were being carried out; the hull construction of a carrier was similar to that of a tanker; the proposed operational area (of the carrier) would have limited fuel supplies; its cargo would have no fire hazard and because AEC reports in 1958 and 1959 had indicated that a carrier would be the first economical nuclear-powered vessel.

A high fuel burn-up ratio is aimed at. Total burning period is given as 3-6 years. The core is divided into three portions so that every 1-2 years, fuel elements in one of the three portions is changed. At the same time, the other fuel elements are re-arranged.



Is burnout clearly understood? This review, which puts forward some new ideas on the subject, follows up our recent article on the spray-cooled reactor

Burnout in liquid cooled reactors - 1

by J. G. COLLIER, B.Sc.(Eng.), A.M.I.Chem.E., Chemical Engineering Division, AERE, Harwell

COOLING OF A heated surface in a channel by a liquid in forced convection is normally more efficient than cooling by a gas or vapour stream. In general, there is a lower temperature difference between the heated surface and the bulk stream, allowing a very much higher heat flow per unit area of surface normal to the coolant flow (heat flux) for the same surface temperature.

However, as the heat flux is continuously increased, a point comes where the cooling process efficiency is drastically reduced, causing, for conditions of constant surface heat flux, a sharp rise in surface temperature. This condition can occur both for liquids whose bulk temperature is below the saturation temperature and for liquids which are boiling or evaporating. The extremely rapid rise of the surface temperature may (though not generally) result in the melting or rupture of the heating surface. Bowring and Roberts (*1*) have made a plea for the precise definition of the terms used in this field; they feel, rightly, that the term ' burnout heat flux ', which literally means the heat flux at which a self-heated element will melt or rupture, has been abused by many writers who use it to denote the heat flux at which the rapid deterioration of the cooling process occurs. Although this common usage of ' burnout heat flux ' is strictly incorrect, it was decided to use the term in this paper because of the lack of an alternative to cover the precise condition of the point at which the rapid temperature rise is initiated. Alternatives suggested by Bowring and Roberts are unacceptable for reasons given later; other terms are used as defined by Bowring and Roberts.

The problem of burnout, the point where a self-heated element will burn out because of the heat flux, is outlined for liquid cooled systems. The hydrodynamic and heat transfer characteristics of a tube in which liquid is being totally evaporated are discussed in detail. Next month's article will discuss the way in which the burnout process can occur in different hydrodynamic regions and review the available experimental evidence. New relationships between burnout heat flux and quality, pressure and mass velocity will be put forward indicating more complexity in the process than has hitherto been suggested.

Previous correlations

The US and Soviet power reactor programmes have been based on water cooled reactor systems. As a result, the problem of ' burnout ' has been extensively investigated experimentally (*2*, *3*) and, to a lesser degree, theoretically (*4*, *5*) in these two countries. Correlation of the experimental data has been attempted but with only limited success. Three types of correlating procedure have been adopted:

(i) Correlations where attempts have been made to look at, and write down equations for, the hydrodynamic and heat transfer processes occurring in the heated channel and to relate these to the 'burnout' condition (*4*, *6*).

(ii) Empirical correlations which have achieved a limited success in that, for the particular range of conditions experimentally tested, it is possible to write equations for use by reactor design engineers which will ensure that a sufficient margin of safety is available over and above the maximum operating heat flux (*2*, *7*). The limitation is that no justifiable extrapolation may be carried out beyond the experimentally covered range of conditions.

(iii) Correlations based on statistical theory which make no assumptions whatever about the mechanisms involved in the ' burnout ' condition but solely attempt a functional relationship between the ' burnout heat flux ' and the numerous experimentally controlled variables (*8*). This type of correlation is also limited by the fact that no justifiable extrapolation is possible.

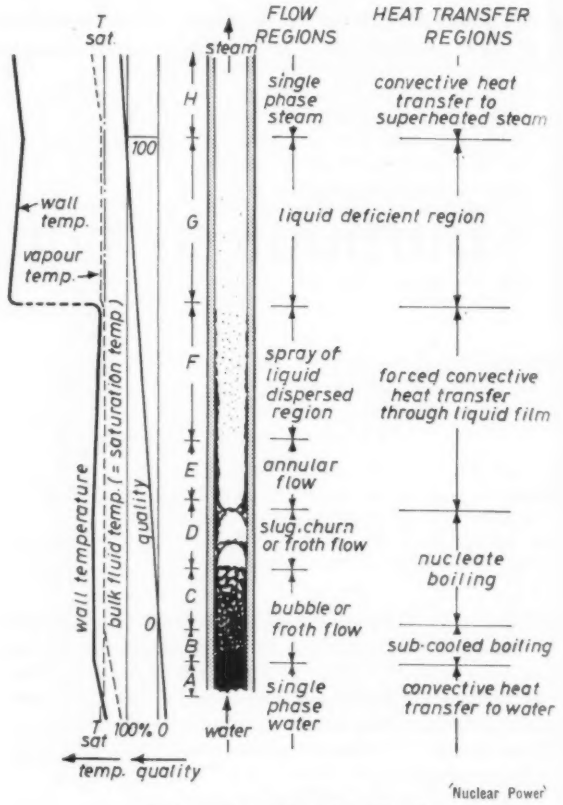
The ultimate objective must be a complete understanding of the fundamental 'burnout' mechanism or mechanisms and only the first of the above three methods of attack can be said to have this in mind. The second and third methods can only be considered as stopgap measures until such time as a generalized method based on the physical processes occurring in the channel is possible. This paper's object is to give a qualitative picture of the hydrodynamic and heat transfer processes which appear to be occurring and, from these observations, to draw certain conclusions regarding the mechanisms of 'burnout'. Only the conditions in a simple vertical tube will be dealt with.

HYDRODYNAMIC AND HEAT TRANSFER CONDITIONS

Consider a long vertical tube, to the walls of which is applied a uniform low heat flux (Fig. 1). Cold water is introduced under forced convection at the base. In the lowest section, A, the water is simply increasing in temperature and the hydrodynamics and heat transfer are governed by the ordinary laws of forced convection. As the temperature of the water rises and approaches the boiling point, the surface temperature which is in excess of the bulk temperature finally reaches the saturation temperature. When the surface temperature exceeds the saturation temperature by a few degrees, the liquid in contact with the heated surface is superheated to a sufficient amount to allow bubble formation at favoured points of nucleation. The vapour bubbles grow large enough to detach and travel into the cooler bulk stream where they collapse. This section, B, is known as the ' subcooled boiling region '.

When the bulk stream temperature of the liquid reaches the saturation value, the detached bubbles no longer condense but become dispersed in the turbulently flowing water. This region, C, is known as the ' nucleate boiling region with vapour generation ' and the two-phase hydrodynamic flow pattern is termed ' bubble flow '.

Further up the tube, the increase in bubble concentration is such that bubbles start to coalesce to form larger bubbles or slugs. Region D represents an unstable condition in which the phases are becoming inverted from continuous phase-water to



Regimes of two-phase flow (Fig. 1)

continuous-phase steam giving the hydrodynamic flow patterns of ' slug flow ', ' churn flow ' or ' froth flow '. In region E, we can see that the steam has increased in proportion to the water to the point where it has become the continuous phase. The water has been displaced to the walls and is now in the form of a thin, relatively slow moving film of superheated fluid while the steam flows as a high velocity gas in a central core. This flow pattern is termed ' annular flow '. In practical cases, owing to the collapse of bubbles there is usually also some spray in this region.

Still further up the tube, the steam velocity in the core has become high enough for the resulting shear forces to begin to disrupt the surface of the film dispersing the liquid in the form of droplets in the high velocity gas core. Further increases in steam velocity yield a marked increase in the proportion of spray; in fact, the bulk of the water now flows in this dispersed form. This region, F, is termed the ' spray or liquid dispersed region '. There is no sharp boundary between E and F.

Throughout regions E and F, the thickness of the liquid film on the wall decreases until a point is reached where the film disrupts and vanishes. Above this point, region G, there is simply a dispersion of droplets in the steam—the ' liquid deficient region ' which changes over to dry or superheated

NOMENCLATURE

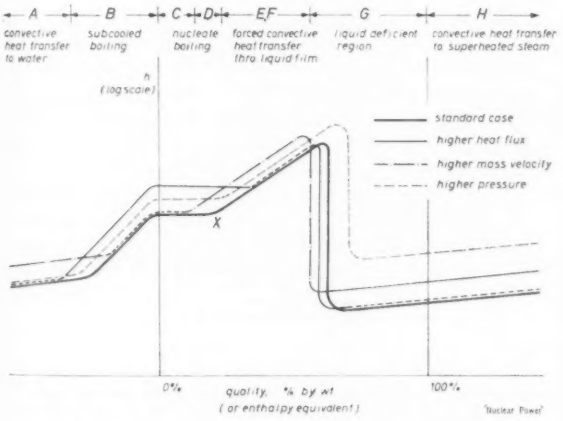
A	total heated area of test section (ft²)
b	parameter in equation (1)
D	diameter of heated test section (ft)
G	total mass velocity (lb/h ft²)
h	heat transfer coefficient (Btu/h ft² °F)
j	constant in equation (1) (dimensionless)
k_g	droplet mass transfer coefficient (ft/h)
L	length of heated test section (ft)
P	pressure (lbf/in²a)
Q	total heat transferred (Btu/h)
Q/A	heat flux (Btu/h ft²)
T	temperature (°F)
v	specific volume (ft³/lb)
V_B	the ' boiling velocity ' (as used by Vanderwater) (ft/h)
x	steam quality (% by wt.)
y	thickness of liquid film (ft)
ΔT_{sub}	degree of subcooling (°F)
ΔT_{sat}	degree of superheat (°F)
λ	latent heat (Btu/lb)
σ	surface tension (lbf/ft)
$\Delta\sigma$	difference in surface tension of liquid caused by heat transfer (lbf/ft)

steam in region H. In regions G and H heat transfer occurs by the normal convective processes as applied to dry saturated steam; although in region G there is room for argument about the properties of the coolant to use in calculations.

The subcooled boiling region

The condition of burnout in a liquid cooled channel cannot be initiated while the surface temperature is below the saturation temperature, i.e., in region A. In the subcooled boiling region, the heating surface temperature remains essentially constant at a number of degrees above the saturation temperature while the bulk steam temperature is increasing to the saturation temperature. The amount by which the surface temperature exceeds the saturation temperature is known as the ' degree of superheat '; the difference between the saturation and bulk stream temperatures is known as the ' degree of subcooling '. At higher heat fluxes, the onset of subcooled boiling is encountered at higher degrees of subcooling and the vapour bubbles may grown and collapse while still attached to, or even sliding along, the heating surface. The heat transfer coefficient is greatly enhanced in the subcooled boiling region. Figure 2 shows the variation of heat transfer coefficient in the subcooled region and the quality region.

As the heat flux is increased so the degree of superheat is increased, this being dependent on approximately the cube root of the heat flux. The population of bubble nucleation centres appears to increase as the square of the heat flux (*9*). Hence the heat removed per nucleation centre falls with increase of heat flux; this is believed to be due to local convection between the bubbles being responsible for most of the heat transfer and being restricted by contiguity of the sites. Nevertheless, the rate of bubble production at each centre also increases slowly with increasing heat flux until the bubble centres are so closely spaced and bubbles follow each other so frequently that they interfere with one another. The form of this interference is not positively known; one suggestion (*4*)



Variation of heat transfer coefficient with quality (Fig. 2)

is that the bubbles join together to form continuous oscillating vapour columns near the surface and that interaction of these unstable vapour columns occurs, causing the area of the heating surface between the vapour columns to be starved of liquid. An unstable vapour patch momentarily insulates the heating surface, causing a local rise in the surface temperature. Very small increases in the heat flux above this point will cause many vapour columns to interact, forming large semi-stable patches of vapour on the surface which allow quite large surface temperature rises. Above a critical temperature (the Leidenfrost point), (*10*) the heating surface can no longer be wetted by the liquid and the vapour blanket becomes permanent over the surface. As this is occurring, the temperature of the surface, now completely insulated by the vapour film, will have almost instantaneously increased by a thousand degrees or more and stable film boiling will be initiated. This is the probable mechanism of ' burnout ' in the subcooled boiling region.

Experiments (*7, 11*) carried out in the subcooled boiling region indicate that an increase in the degree of subcooling (ΔT_{sub}) or the liquid mass velocity (G) increases the value of the 'burnout' heat flux. At constant values of the subcooling and the mass velocity, the 'burnout' heat flux appears to decrease with increasing pressure in the range 500–2000 lbf/in² for water. It has been suggested in the USA(*2*) that the ' burnout heat flux ' is also dependent on the length to diameter ratio(L/D) of the test section. However, Bowring (*12*), having re-examined the experimental data on which the suggestion was based, has found no conclusive evidence of an effect for high degrees of subcooling (>20°F).

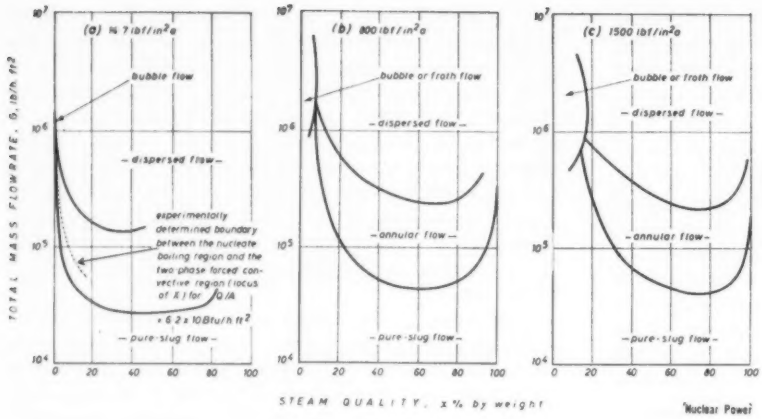
Nucleate boiling in the quality region

The primary variable in the regions C to H is the ' quality ' of the mixture (the ratio of the steam flowrate to the total mass flowrate). The boundaries of the regimes of flow are not at all clearly defined, particularly at high pressures where no visual observations have been made. Nevertheless, it is possible to construct a flow pattern chart for steam and water based on visual observations at low pressures, usually with air and water. One such chart has been prepared recently by Goldmann *et al* (*13*) using Baker's (*14*) flow pattern chart as modified by Isbin *et al* (*15*). The various two-phase hydrodynamic flow patterns are indicated as functions of the quality (x%) and the total mass velocity (G lb/h ft²) for three different pressures (Fig. 3).

The first observations to be made are that the bubble or froth flow region which most people associate with water boiling at high pressure in a channel, occurs only up to a quality of 20% by weight at pressures even as high as 1500 lbf/in² and that for mass flowrates of interest in nuclear reactors (greater than 10^5 lb/h ft²) most of the quality region is either in the annular or dispersed flow regions.

The mechanism of heat transfer in the bubble and froth regions is that of ' surface nucleate boiling '. Like the subcooled boiling process, a thin layer of liquid near the walls is superheated to a sufficient degree to allow nucleation at the walls. Indeed, the processes of subcooled boiling and nucleate boiling in the quality region are essentially the same near the heating surface. The change from one region to the other is a very smooth transition. This is shown in Fig. 1; it is seen that the degree of superheat (ΔT_{sat}) remains unaltered by the change. The mechanism of 'burnout' in the nucleate boiling region is also essentially the same as that described for the subcooled case. The theory of 'burnout' based on the interaction of vapour columns was, in fact, first proposed by Zuber (*4*) for the saturated pool boiling process and later applied to the subcooled condition.

The effects of the independent variables, heat flux (Q/A), total mass velocity (G) and system pressure (P) on the heat


(a) 14.7 lbf/in²a
(b) 800 lbf/in²a
(c) 1500 lbf/in²a
bubble flow
bubble or froth flow
– dispersed flow –
– annular flow –
experimentally determined boundary between the nucleate boiling region and the two phase forced convective region (locus of X) for G/A = 6.2 x 10⁶ Btu/h ft²
– pure-slug flow –
TOTAL MASS FLOWRATE, G, lb/h ft²
STEAM QUALITY, x % by weight
'Nuclear Power'

Flow pattern boundaries for the steam-water system at various pressures; (a) 14.7 lbf/in²a; (b) 800 lbf/in²a; (c) 1500 lbf/in²a (Fig. 3)

transfer coefficient are shown in Fig. 2. It can be seen that an increase in the pressure or heat flux increases the coefficient but that the mass velocity appears to have little effect.

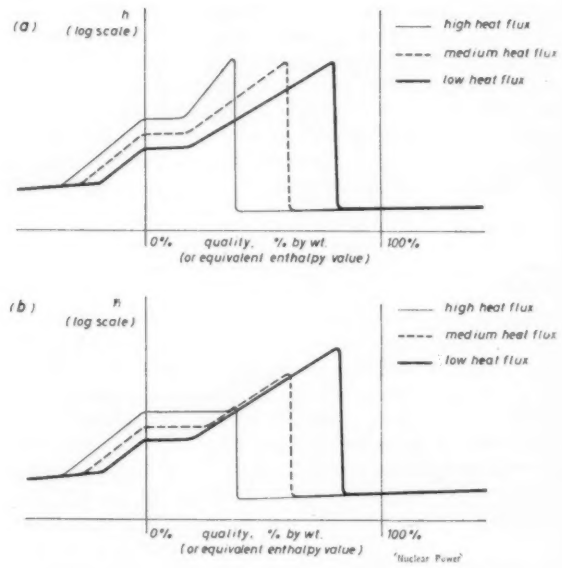
Transition from nucleate boiling

As the quality increases through the nucleate boiling region, a point (X) is reached where a fundamental transition in the mechanism of heat transfer takes place (*16*). The process of 'boiling' is replaced by the process of 'evaporation' according to the definition of Roberts and Bowring (*1*). This transition is brought about by a change in the hydrodynamic flow pattern from bubble or froth flow to annular or dispersed flow. In the latter regions, the thickness of the thin liquid film on the heating surface is usually such that the effective thermal conductivity is sufficiently high to prevent the liquid in contact with the wall being superheated to such a temperature as to allow bubble nucleation. Heat is now carried away from the surface by forced convection in the film to the liquid film-vapour interface where evaporation occurs. Since nucleation of bubbles is completely suppressed, the heat transfer process can no longer be called 'boiling'. The region beyond the transition point has been referred to as the 'two-phase forced convective region' of heat transfer.

It can be demonstrated that this transition in the heat transfer process is closely related to and probably caused by the change in hydrodynamic flow pattern from bubble or froth flow to annular or dispersed flow. Superimposed on Fig. 3*a* is the experimentally determined boundary between the nucleate boiling region taken from heat transfer measurements made with steam-water flow in a vertical annulus at pressures just above atmospheric (*16*, *17*). The exact locus of the transition point (X) as a function of mass flowrate and quality is dependent on the level of heat flux. This can be seen from Fig. 2. The curve shown on Fig. 3*a* is drawn for a heat flux of $6{\cdot}2 \times 10^4$ Btu/h ft². However, if a higher heat flux had been chosen the curve would have been displaced very slightly to the right. It is suggested that the transition between bubbie or froth flow and annular or dispersed flow will cause a transition in the heat transfer process at higher pressures also and that a fair approximation to the locus of the point X at these higher pressures will be given by this hydrodynamic boundary (Figs. 3*b* and *c*).

The two-phase forced convective region

Heat transfer in this region is characterised by an increasing coefficient with increasing quality of the steam-water mixture (Fig. 2). Heat transfer through the liquid film is entirely governed by the hydrodynamic conditions of the film (i.e., its thickness, velocity distribution, etc.). These in turn are largely governed by the conditions in the vapour core which exerts the shearing force at the liquid-vapour interface. Generally, an increased vapour velocity, caused either by an increase in quality at constant mass velocity or an increased mass velocity at constant quality, results in a decrease in film thickness, an increase in the effective thermal conductivity



Effect of heat flux upon heat transfer coefficient: (a) as deduced from Vanderwater's work; (b) as suggested by present work (Fig. 4)

of the film and higher heat transfer coefficients. Unlike the boiling region, the level of heat flux has only a minor effect caused by modification of the physical properties of the liquid film arising from slight variations in the mean film temperature.

For most conditions, the liquid film is extremely thin (between one and ten thousandths of an inch) and with heat fluxes of the order of 10^5–10^6 Btu/h ft² it would be totally

evaporated in a short length; it could be argued that it is only the fact that it is being continuously replenished by absorbing droplets from the vapour core that prevents its disappearance. (This aspect will be returned to later.) In addition, the surface of the film is not smooth but wavy and the very high shearing forces tend to re-entrain liquid from the film and disperse it in the core as droplets. Thus, there is a continuous mass interchange between the droplets in the core and the liquid film. It should also be noted that droplets entering the liquid film diffuse through a current of vapour travelling away from the film surface with a low velocity (approximately 1/500th of the velocity parallel to the surface).

Heat transfer coefficients in the two-phase forced convective region are very high. Values up to 10,000 Btu/h ft² °F have been reported for the water-steam system at substantially atmospheric pressure (*16*) while at moderate pressures (300–700 lbf/in²a) coefficients as high as 40,000–60,000 Btu/h ft² °F have been measured (*18*, *19*).

It is generally agreed that 'burnout' in this region is due to the disruption of the liquid film on the heating surface. This, clearly, is in no way associated with the mechanism of 'burnout' in the 'boiling' regions. It is here that the difficulty regarding terminology arises; the terms 'critical heat flux'(*1*) or 'departure from nucleate boiling (DNB)'(*2*) are not acceptable.

Various workers have taken the film breakdown concept as a basis for their correlations. Cicchitti *et al.* (*6*), Vanderwater (*20*) and Goldmann *et al.* (*13*) all consider that the onset of the 'burnout' condition in this region is governed by the diffusion of liquid droplets to the heated wall. Cicchitti *et al.* (*6*) and Goldmann *et al.* (*13*) postulate that the 'burnout' point is reached when the net replenishment rate of water in the form of droplets entering the liquid film equals the rate of vaporization at the film surface.

Vanderwater (*20*), on the other hand, set up two simultaneous differential equations describing the liquid distribution in a channel taking into account the diffusion of droplets from the vapour core, the re-entrainment of liquid from the film surface and the vaporization of liquid in the film. He assumed that 'burnout' occurred as the liquid film thickness described by these equations reduced to zero or a very low value.

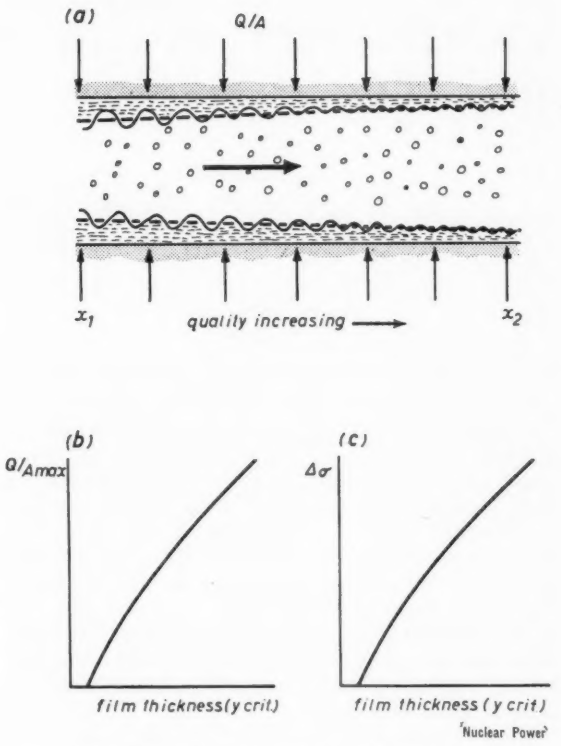
Unfortunately, due to the lack of data on the diffusion and re-entrainment processes, all three workers had to test their models by applying their respective equations to experimental 'burnout' data to evaluate the unknown relationships governing the mass transfer coefficient and the re-entrainment function in terms of the independent variables.

This method led Vanderwater to some interesting conclusions. In his equations the droplet mass transfer coefficient (k_g) was related to the total mass velocity (G) by an equation of the form

$$k_g = bG^j \qquad (1)$$

Vanderwater concluded that the index j had a best fit value of $-0{\cdot}5$ whereas normal molecular mass transfer would yield a value of j equal to $+0{\cdot}8$. Vanderwater attributed this remarkable conclusion to two factors. First, the effect of the current of vapour travelling away from the film and, secondly, the fact that droplets do not behave in the same manner as molecules.

It has been noted earlier that the current of vapour travelling away from the film is only a very small fraction of the linear gas velocity parallel to the film surface. Vanderwater argued that the droplet mass transfer coefficient should decrease with increase of the velocity of steam away from the film surface (V_B). He suggested that V_B increased as the mass velocity parallel to the film surface increased. (The reason for this is not stated and is by no means evident; by definition $V_B = ([Q/A]\ (v_g - v_l)/\lambda)$, whereas at constant pressure, the only variable which affects V_B is the heat flux Q/A.) From this he argued that the droplet mass transfer coefficient should decrease with increasing mass velocity.



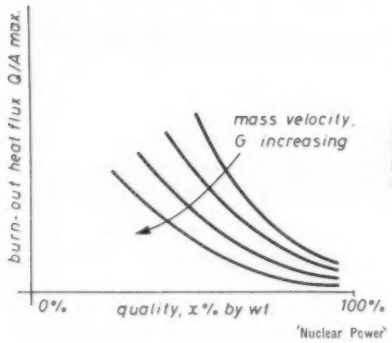
Factors affecting the breakdown of a heated liquid film (Fig. 5)

The second reason quoted would not appear to alter significantly the magnitude or sign of the index j based on the evidence of Alexander and Coldren (*21*) who measured the droplet mass transfer coefficient for the air-water system. They observed a value of j equal to $+1{\cdot}17$—not very far removed from the value for molecular mass transfer.

If Vanderwater's theory accurately describes the liquid distribution in the channel at various points along the length, the thickness of the liquid film before the 'burnout' point would be affected by the level of heat flux (since V_B in Vanderwater's equations markedly affects both the droplet mass transfer coefficient and the re-entrainment function in the same sense). This variation of film thickness with heat flux at nominally similar conditions of quality, mass velocity and pressure would manifest itself as a similar change in heat transfer coefficient before the 'burnout' point (Fig. 4*a*). This is contrary to what is observed at both low (*16*) and medium pressures (*18*, *19*). Indeed, the level of heat flux is shown to have little or no effect on the heat transfer coefficient before 'burnout' for similar conditions of quality mass velocity and pressure (Fig. 4*b*).

A suggested mechanism for 'burnout' in the two phase forced convective region

Let us assume that, under most cases (although probably not all) the rate of mass interchange between the vapour core and the liquid film is *not* the limiting process in the 'burnout' mechanism. And also that the level of heat flux being transferred across the liquid film has little effect on the mass interchange processes and on the liquid film thickness, all other conditions remaining constant. No attempt can or will be made to justify these assumptions at present.



Relationship between main variables from suggested mechanism (Fig. 6)

Consider a section of the heated tube (Fig. 5*a*) through which the steam-water mixture is passing. The liquid film thickness is shown as a function of quality rather than length since the diagram is thus made independent of the heat flux level. It is suggested that there is a maximum limiting value of heat flux which can be sustained by a liquid film of a certain thickness prior to the disruption of the film. As the thickness of the liquid film is increased, so the maximum heat flux which can be sustained also increases (Fig. 5*b*). It will be noted that the curve does not pass through the origin since even when the surface is unheated, disruption of the film occurs at a finite value of film thickness.

The phenomenon of 'dewetting' of surfaces over which liquid films are flowing under conditions of mass (*22*) or heat transfer (*23*) is well known in chemical engineering. The mechanism of dewetting is, however, not at all understood. Norman *et al.* (*22, 23*) have suggested that the phenomenon may be explained by consideration of surface tension differences which appear as a result of the mass or heat transference. The liquid film is not of uniform thickness due to the presence of ripples. When heat is transferred through the film, the thinner parts attain a higher temperature and hence a lower surface tension than do the thicker parts. Thus the thicker parts of the film tend to draw liquid from the thinner parts with the result that the film becomes even more unstable and eventually breaks down.

The postulated relationship between the mean film thickness just before 'burnout' (y_{crit}) and the 'burnout heat flux' (Q/A_{max}) (Fig. 5*b*) may now be explained in terms of Norman's hypothesis. The mean film thickness (y_{crit}) can equally well be represented as a function of the temperature difference between the wall and the liquid film-vapour core interface (the saturation temperature) at the 'burnout' condition. If it is assumed that the thin parts of the film approach the wall temperature and the thick parts, the temperature at the film-vapour core interface (T_{sat}), then the difference in surface tension ($\Delta\sigma$) can be evaluated (Fig. 5*c*) (c.f. Fig. 16, ref. (22).

Norman also suggested that the actual value of the average liquid surface tension should be introduced into the correlation by plotting the product $\Delta\sigma \times \sigma$ against the film thickness. However, the inclusion of σ as a product has no easily visible physical significance (*24*).

Norman's hypothesis shows the relationship in Fig. 5*b* to be credible. Let us now demonstrate the effects of quality and mass velocity on the 'burnout heat flux' using this relationship. As the quality (x) increases at constant mass velocity (G), the linear vapour velocity is increased, causing the liquid film to be thinned so reducing the maximum flux which can be sustained. If the mass velocity is increased at constant quality then both the water and steam flowrates are increased. Collier and Hewitt (*25*) have shown that at high mass velocities, where a high percentage of liquid is already entrained in the vapour stream, the film thickness and film flowrate are dependent almost entirely on the gas velocity alone. Any addition of water above a critical value set by the gas velocity results in all that water being entrained in the gas core, leaving the film thickness and film flowrate virtually independent of the water flow to the channel. These conditions prevail for the majority of the experimental 'burnout' measurements taken in the forced convective region. The effect of an increase in mass velocity then is virtually that of increased vapour velocity, again causing a reduced film thickness and a reduced maximum heat flux. These effects are shown qualitatively in Fig. 6. No prediction on the effect of pressure can be made from this qualitative model.

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Safety and serviceability in reactor safety circuits—1

by U. BROCCARDO, Dott. Ing. Nuclear Department, Kennedy and Donkin

The statistical approach to reliability in the design and testing of missiles and rockets has been standard practice for many years; this approach has been extended to the problem of reactor and control instrumentation reliability

THE ADVENT OF nuclear power stations has made a new approach to the design of instrumentation and safety circuits necessary. The maximum degree of safety in operation is required. But heavy financial losses are incurred if a reactor is tripped unnecessarily, with the failure of perhaps hundreds of megawatts of generating capacity for a period of some hours.

As the reliability of electronic instruments is probably below that required, research has been carried out into methods of assuring safe but secure operation. What is required is a definite and rapid tripping of the reactor whenever an incipiently dangerous condition genuinely exists, combined with stability against random failures of equipment. This can be achieved by applying principles of redundancy and coincidence to the circuit design.

The original '2 out of 3' arrangement was arrived at almost intuitively but more sophisticated systems were developed later, based on probability analysis. However, it does not seem that a quantitative definition of safety and serviceability, such as is proposed here, has been attempted previously.

SERVICEABILITY

Aiming at the economic optimum between serviceability and safety, it is clear that the probability of an event (spurious trip or accident) cannot be immediately converted into financial terms. A financial sum can be associated only with the expected occurrences of these events.

Therefore, the expected occurrences of spurious trips in 20 years will be assumed to represent the degree of serviceability of the safety system. It should be emphasized, however, that according to this definition, serviceability is the greater the less the number of spurious trips.

SAFETY

For the same reason, the expected occurrences of dangerous conditions in 20 years should be assumed to represent the degree of safety.

An unsafe condition is not necessarily a dangerous condition as the latter implies the simultaneous occurrence of a reactor fault or of a reactor condition in which the faulty part of the instrumentation is required to work properly.

In the absence of any information about this last point, the pessimistic assumption is made that every unsafe condition is a dangerous condition and the expected occurrences of unsafe conditions in 20 years will be assumed to represent the degree of safety of the system.

Again, this figure would rather represent the degree of danger but it will be used because of its immediate conversion in terms of financial losses.

PROCEDURE

The starting point is a certain figure, obtained experimentally or estimated, for the fault rate of a given channel. The first step is to calculate the probability of finding the channel still working or faulty. From this, using the multiplication law, the probability of a coincidence of faults for a certain arrangement will be worked out. This will also represent the probability of a spurious trip or of an unsafe condition. Finally, from these probabilities, one must go back to the relevant rates and expected occurrences.

Reliability in safety circuits is of paramount importance considering the radiation hazards involved and the difficulties of maintenance. This paper attempts to set a realistic limit to the problem by quantitatively defining safety and serviceability and by showing that to some extent these requirements are conflicting.

CHANNEL FAULT RATE

The channel fault rate, which will be expressed throughout in faults/year, is not a probability itself and cannot be treated as such. It could be obtained experimentally but lack of experimental data forces us to estimate it. We shall assume three categories of channels with good, medium and poor reliability respectively, and we shall arbitrarily assume a safe fault rate of 0·1, 1 and 10 faults per year respectively.

E

In the absence of information, the unsafe fault rate will be assumed 1/10 of the safe fault rate for the same channel.

The guard line trip contact should be considered as the output of the channel so far as the fault rate is concerned.

RANDOMNESS OF FAULT OCCURRENCES

The assumption is then made that the occurrences of faults is completely random. It can be argued that this is not completely justified as the causes of the faults can be found and eliminated. A process in which it is possible to go back to the causes of the events should not be a random one because statistics are, in a sense, a measure of our ignorance.

The answer is that the causes of faults are so many, especially in the more complicated equipment, that the suspicion of a systematic occurrence of faults is probably not justified. Moreover, a systematic fault would be soon discovered and its cause eliminated.

Only experience can confirm the random occurrence assumption and improvement in some parts of the equipment could cause the occurrence of faults to become a systematic process in the future.

DURATION OF FAULTS

An important parameter of the problem is the duration of a fault. As will be seen, the probability of a coincidence of faults depends on their duration.

To simplify the problem, reference will be made to the average duration of a fault ; a more prudent assumption is the one referring to the longest fault. Unfortunately, statistical data are not available on the subject and the assumed figures are only a guess.

The time taken to repair a fault is considered as the duration of a safe fault. It will be indicated by the symbol t_s and will be assumed equal to 10^{-4} years, which is approximately one hour.

In case the channel is shorted out during repair, t_s will be reduced to the time taken to put in the shorting plug, after receiving a ' guard line tripped ' alarm.

It can be shown that the average period during which an unsafe fault goes undetected is simply $\frac{1}{2f_t}$, if f_t is the frequency of the routine test.

The time t an unsafe fault lasts can vary between 0 and $\frac{1}{f_t}$. A fault occurring at time t lasts $\frac{1}{f_t}-t$; if the occurring of unsafe faults is completely random, for every fault lasting $\frac{1}{f_t}-t$ there is another, occurring at the time $\frac{1}{f_t}-t$ and lasting t, which gives on the average $\frac{1}{2f_t}$.

Therefore, average duration of an unsafe fault, t_u, can be decreased by increasing the frequency of the routine test.

A routine test frequency of 1 test/week = 52 tests/year gives a value for $t_u = 10^{-2}$ year, while 1 test/day gives (approximately) $t_u = 10^{-3}$ year.

PROBABILITY OF A FAULT

The first step is to work out an expression for the probability of the occurrence of a fault. The channel lifetime can be divided in two parts : time during which it is working, t_w, and time during which it is faulty, t_f. The probability of a fault can then be expressed as :

$$p=\frac{t_f}{t_w+t_f} \qquad (1)$$

Over one year, t_f is equal to f multiplied by t_d, the average duration of a fault. If t_d is expressed as a fraction of a year, the probability will simply be :

$$p=t_d \times f \qquad (2)$$

For example, if the yearly safe fault rate is 10 and the average time taken to repair a fault is one hour, the probability of a safe fault is 10^{-3}.

In other words, the ' favourable ' event is that special period of time, during which a fault occurs and lasts before being repaired. The number of possible events (excluding the possibility of two or more faults occurring simultaneously in the same channel as only the first one would be significant) is obtained by dividing the time considered by the average duration of one fault.

Referring to one year, this is $\frac{1}{t_d}$ and the number of expected occurrences is f, as would be expected.

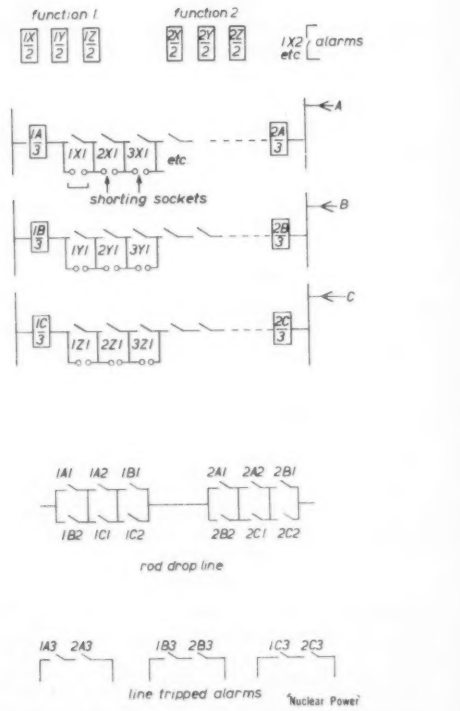
$$p \times \frac{1}{t_d}=\frac{f \times t_d}{t_d}=f \qquad (3)$$

It will be noted that equations (1) and (2) give a value independent of the period of time considered, as implied by the concept of probability.

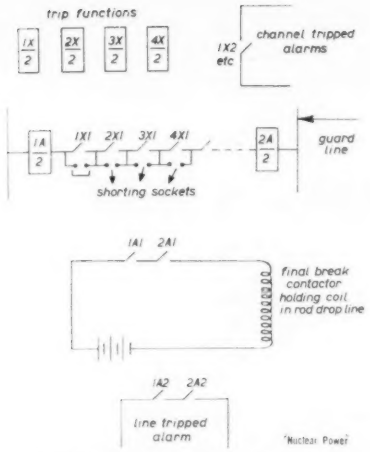
Should the channel fault rate be extremely high, the probability of a fault can theoretically reach the value 1. That means the channel would be out of service all the time and would be of no practical use.

THE ONE SAFETY LINE CASE

Every relay contact in one safety line (Figs. 1 and 2) can be



A '2 out of 3' safety circuit arrangement; three guard lines have their outputs connected in a coincidence circuit (Fig. 1)



Example of a single line safety circuit (Fig. 2)

considered as the output of a particular channel and has, as such, a certain safe and unsafe fault rate. The end line monitoring relays also have their fault rates. The fault rate of the line will depend on both of them.

Serviceability aspect

Every safe fault in the channels or in the monitoring relays will result in a safe fault for the line. Therefore, the line safe fault rate is the sum of the fault rates of the channels and of the monitoring relays.

In the instance of a line containing :

n_1 good channels with safe fault rate f_1

n_2 medium channels with safe fault rate f_2

n_3 poor channels with safe fault rate f_3

2 monitoring relays with safe fault rate f_r

the line safe fault rate will be :

$$f_l=f_1n_1+f_2n_2+f_3n_3+2f_r \tag{4}$$

The safe fault probability for the line will be :

$$p_l=f_lt_s \tag{5}$$

The safe fault rate of the system is :

$$f_s=f_l \tag{6}$$

This also represents the spurious trip rate of the system, as every safe fault in the guard line causes a trip.

The expected occurrences of spurious trips in 20 years, i.e. serviceability, can be obtained simply by multiplying equation (4) by 20. Alternatively, equation (5) can be used, by multiplying it by $\frac{1}{t_s}$ and by 20.

It will be noticed that equation (4) represents the safe fault rate of the contacts IAI and 2AI of Fig. 2, which are the output contacts of the guard line.

Safety aspect

Duplication of the end line monitoring relays is common practice, as an unsafe fault in such a relay would affect every channel in the line and prevent it from tripping.

If only one monitoring relay were fitted, the fault rate of the line would be :

$$\begin{aligned} g_l&=(g_1+g_r)n_1+(g_2+g_r)n_2+(g_3+g_r)n_3 \\ &=g_1n_1+g_2n_2+g_3n_3+(n_1+n_2+n_3)g_r \\ &=g_1n_1+g_2n_2+g_3n_3+ng_r \end{aligned} \tag{7}$$

the letter g referring to unsafe faults.

The negative influence of the last term is overcome by duplication, in which case the calculation is as follows :

The probability of an unsafe fault in one monitoring relay is :

$$q_r=g_rt_u \tag{8}$$

The probability of a coincidence of two such unsafe faults is :

$$q_rq_r=q_r^2=g_r^2t_u^2 \tag{9}$$

The expected occurrences of this coincidence in one year are :

$$g_r'=q^2{}_r\frac{1}{t_u}=g_r^2t_u \tag{10}$$

The unsafe fault rate for the line will therefore be :

$$\begin{aligned} g_l&=g_1n_1+g_2n_2+g_3n_3+ng_r' \\ &=g_1n_1+g_2n_2+g_3n_3+ng_r^2t_u \end{aligned} \tag{7'}$$

The probability of an unsafe fault for the line is :

$$q_l=g_lt_u \tag{11}$$

As every unsafe fault in the guard line causes an unsafe condition for the reactor, the unsafe (=dangerous) condition rate of the system is :

$$g_s=g_l \tag{12}$$

The expected occurrences of unsafe conditions in 20 years, i.e. the degree of safety of the system, will be obtained either by multiplying equation (12) by 20 or by multiplying equation (11) by $\frac{1}{t_u}$ and then by 20.

Again, equations (7) or (7') represent the unsafe fault rate of the contacts IAI and 2AI of Fig. 2.

It should be emphasized that equations (7) and (7') assume that no 'backing up' exists between one channel and the others, i.e. if a situation arises in the reactor requiring a particular channel to take action and the channel has an unsafe fault, it is assumed that no other channels will be capable to back it up before serious damage is caused.

APPENDIX

Probability and expected occurrence

Probability—Probability can be defined as the ratio of the number of 'favourable' events to the number of possible events. More precisely, it is the limit of the ratio of the favourable events to the total events when the number of trials tends to infinity.

Multiplication law—The probability of two events occurring together is the product of their individual probabilities.

Addition law—The probability of one or the other of two different mutually excluding events occurring is the sum of the individual probabilities. Both the multiplication and addition laws can be extended to include any number of events.

Expected occurrences—The 'expected occurrences' of a certain event are obtained by multiplying the probability by the number of trials.

Some definitions

Guard line or safety line—A chain of relay contacts operated by the various detecting devices with the continuity of the line being monitored by relays at one or both ends of the circuit.

Channel—All equipment through which the information on the behaviour of a certain function is obtained and conveyed to the guard-line trip contact. The detector and the contact are respectively the inlet and the outlet of the channel.

Redundancy principle—To increase the safety, more than one channel is fitted for the same function and it is expected that at least one will work properly. The reactor could then be tripped by a signal from any one of a number of channels but such an arrangement would be more sensitive to spurious trips.

Coincidence principle—If r out of m channels are required to operate before the reactor trips, then $(m-r+1)$ of them must have an unsafe fault simultaneously before an unsafe condition can arise. Serviceability and safety now no longer depend only on the equipment characteristics but they also become a feature of the safety system itself and can be increased as required; the only limitation is the cost and complexity of the system.

The difficulty of insulating metallic thermocouples in a high temperature graphite reactor may lead to the use of ceramic devices

Thermocouples for high temperatures

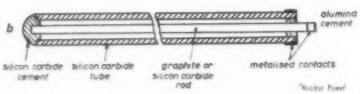
ONE OF THE PROBLEMS to be faced in the design of the high temperature gas cooled reactor is that pyrometry tends to become difficult with the rise in temperature where graphite is involved. At around 1500°C metallic thermocouples react with graphite, and above 1850°C the insulation resistance of refractory materials falls to an unacceptable level. With insulation by air spacing, ceramic thermocouples are a promising alternative for a compact device.

Looking at this problem, Morganite Research and Development Ltd have been working on graphite, silicon carbide and tungsten, and have produced tubes and rods made into thermocouples of concentric design, with sizes varying from ¼ in o.d. × 6 in long to 1in o.d. × 3 ft long. Tests of over 100 h at 1750°C carried out in a carbon tube furnace indicate a promising potential in the 1500°–2500°C range, dependant on the atmosphere and the length of service required (Tables 1 & 2).

Graphite The materials used were the standard Morgan extruded electrographite grades—EY4, EY8348 and EY9—heat-treated to about 2500°C. Spectrographic analysis of the heated ends revealed the effect of impurities on the thermoelectric power (Fig. 1), the greatest being caused by boron. Other impurities in amounts greater than 100 ppm also affected the output. In spite of the variations experienced, thermocouples have been produced on a laboratory scale suitable for high temperature graphite reactors and carbon tube furnaces. Large scale production is not yet practicable, however. Running tests (Table 1) of 100 h or more were completed without failure. Long term stability with an average output around 20μV/°C at over 1850°C is under investigation.

With tungsten used as the inner member (Fig. 2*a*) the overall diameter of the thermocouple can be reduced. Giving an output around 15μV/°C, used in air it has a short term application at 1300°–1750°C; particularly for dip immersion in molten metal (excluding steel).

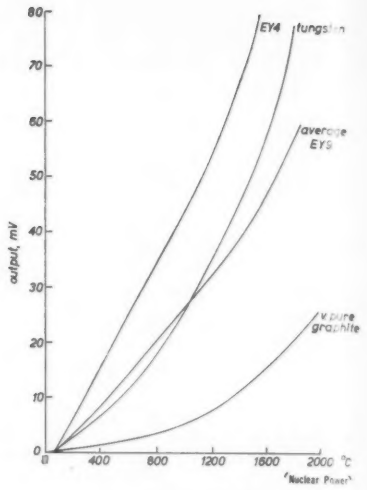
The graphite/tungsten thermocouple gives an output of around 15μV/°C from 1000°C–1750°C with a reversal of e.m.f. at lower temperatures. It is useful when slim couples 1–3 ft long are required for short term use at 1300°–1700°C (Fig. 2a)



The all-silicon carbide thermocouple has an average output of 50μV/°C. Concentric types have been made up to 30 in long x 22 mm o.d. (Fig. 2b)

Silicon carbide The standard couple developed (Fig. 2*b*) consists of a tube 10 mm o.d. × 12 in long using a 3 mm dia. electrographite rod as the centre element. It gives an output of 150–200μV/°C. To reduce the oxidation when used in air, the graphite was insulated by means of a sprayed alumina coating and the annular space was packed with carbon black. Although the life of the couple was prolonged failure eventually occurred through the thinning of the graphite rod. Because of the inability of the alumina insulant to stand up to high temperatures, above 1800°C a gas insulation is used.

A range of all-silicon-carbide thermocouples has been developed using grades of material giving different outputs. These have been produced in sizes up to 3 ft long × 22 mm o.d. The average output given is 50μV/°C but an experimental couple consisting of two cemented strips, one of the strips having been doped gave an output of over 200μV/°C. The high temperature test on the SiC/SiC couple showed some perishing of the hot end in air but insufficient to cause serious affect (Table 1).



Output curves for electrographites (with platinum as the reference) Fig. 1

Reference

'High temperature thermocouples using non-metallic members' by Mr E. Franks (Morganite Research & Development Ltd) Paper presented to the Temperature Symposium, Ohio, in March 1961.

TABLE 1 High temperature tests on ceramic thermocouples.

TYPE	SIZE	TEMP., °C	OUTPUT, mV	LIFE, h	ATMOSPHERE
SiC/C	10 mm o.d. × 18 in	1750	350	115	C tube $+N_2$
SiC/C (C black packed)	,, ,,	1750–2000	—	25*	Oxidizing
SiC/SiC	1 in o.d. × 3 ft	1500–1750	80–100	50*	Oxidizing
C/C	1 in o.d. × 2 ft	1750	72	100*	C tube $+N_2$
C/W	1 in o.d. × 2 ft	1750	12	200*	C tube $+N_2$

*Without failure.

TABLE 2 Expected life of thermocouples at temperature (°C)

THERMOCOUPLE TYPE	*	OXIDIZING ATMOSPHERE 1	2	3	4	CARBONACEOUS ATMOSPHERE 1	2	3	4	HIGH VACUUM 2	4
SiC/SiC		1550	1750	1850	2100	1700	1750	1900	2100	1200	1800
SiC/C		400	600	1850	2100	1700	1750	1900	2100	1200	1800
C/C		Unsuitable			2500	1850	2000	2500	2600	1750	2500
C/W (alumina insulators)		Unsuitable			1750	U	1550	1700	1750	1450	1600

*1 Continuous service—over 1000 h 2 Long service—around 100 h 3 Short service—around 10 h 4 V.Short service—some minutes (& dip immersion).

This pioneer plant at Dounreay handles fuel elements having a fission product activity amounting to thousands of curies

Experience in reprocessing enriched reactor fuel elements

by G. W. LLEWELYN and R. H. ALLARDICE, Chemical Processing Group, UKAEA, Dounreay

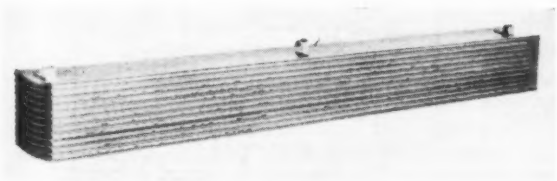
THE MTR CHEMICAL PLANT serves Materials Testing Reactors at Dounreay, Harwell, Australia, Denmark and West Germany and the Merlin type research reactors which use the same basic fuel element.

MTR fuel assemblies consist of thin aluminium clad enriched uranium aluminium alloy sheets brazed to aluminium side spacers to form a box containing ten uranium-bearing plates and two aluminium cover plates (see Fig. 1).

A high proportion of the uranium-235 has been fissioned at the time of discharge from the reactor and each element has a fission product activity of hundreds of thousands of curies. The elements are cooled for 120 days before processing to permit the decay of short-lived fission products, particularly iodine and uranium-237.

The flow diagram for the plant is shown in Fig. 2. The uranium-bearing plates are separated and dissolution is carried out in nitric acid containing mercuric nitrate as a catalyst to anion deficient conditions to give a basic aluminium nitrate complex of the form $Al(OH)_x(NO_3)_{3-x}$. This solution is highly viscous and very dense and has an enriched uranium content of a few gms per litre and a fission product content of hundreds of curies per litre.

The solution is fed to stirred mixer settlers counter-current to a solution of 5% tri-butyl phosphate in odourless kerosene and solvent extraction of the uranium and a small percentage of the fission products takes place. The loaded solvent is then stripped with a solution of aluminium nitrate in nitric acid to remove loosely complexed fission products and is backwashed with dilute nitric acid. The flow through the mixer-settlers is shown diagrammatically in Fig. 3.



MTR fuel element assembly consisting of thin aluminium clad enriched uranium-aluminium alloy sheets brazed to aluminium side spacers to form a box containing ten uranium bearing plates and two aluminium cover plates (Fig. 1)

The first cycle of solvent extraction is designed to achieve a decontamination factor of fission products with respect to uranium of 1×10^4. The first cycle raffinate solution containing the bulk of the fission product activity is discharged to underground tanks for permanent storage and the backwashed solvent passes to Holleymott contactors for washing with caustic soda and dilute nitric acid to remove degradation products and fission product activity before recycling.

THE DOUNREAY CHEMICAL PLANT

Two plants have been built at Dounreay to process irradiated enriched fuels from the Fast Reactor and from a number of Materials Testing Reactors in this country and abroad. The functions of the chemical plants are to recover the unused fissile material and to decontaminate it from fission products, inert fuel diluent and chemical impurities. These functions are performed in a conventional solvent extraction process which is carried out in stirred mixer-settlers placed behind biological shielding.

The product from the first cycle process is conditioned continuously with strong nitric acid and ferrous sulphamate is added to reduce the parasitically formed plutonium-239 to the inextractable tri-valent condition. A second extraction, stripping and backwashing process is carried out in mixer-settlers, again using 5% TBP/OK but under acid conditions, to further purify and concentrate the enriched uranium. The pure uranyl nitrate solution which contains a negligible quantity of fission product activity per kilogram of uranium and less than 200 ppm of impurities such as iron, chromium, nickel and aluminium, is pumped to the Billet Production Plant for conversion to metal under alpha-active conditions.

The raffinate from the second cycle is monitored and can be diverted to the evaporation and storage plant or to low active drain for disposal to sea, depending upon whether the level of fission product activity is above prescribed limits or not. The backwashed solvent is washed in the same way as the first cycle solvent for re-use.

PHILOSOPHY BEHIND PLANT LAY-OUT

There are two main divisions in the building, the highly shielded cells where the entire purification process is

carried out, and the working area. Figure 4 shows a horizontal section of the plant through the shielded cells and working area.

The shielded section is subdivided into two identical highly active cells and one medium active cell. After completion of the inactive commissioning programme, the entrance to the highly active cell to be used for active processing was bricked over and no further access will be possible without extensive decontamination. Entrance to the medium active cell is normally not allowed but a limited time may be spent within the cell provided the time permitted is previously deduced from the measured radiation level. After a short decontamination period, maintenance work and modifications are possible in the medium active cell. The second highly active cell has been used to process unirradiated uranium-aluminium alloy material but no irradiated elements have been processed to date so that modifications indicated by the operating experience in the other highly active cell may be fairly readily carried out.

The working area surrounds the active cells as an annular space within the general framework of the building, and, in order to facilitate plant operation and supervision, is subdivided into a green and an amber area. Within the amber area the operations which involve some risk of radioactive contamination are carried out, for example, breakdown of the fuel elements under water prior to charging to the dissolver, sampling of process streams, and metering of medium active feeds to the mixer-settlers. The operations within the active cells are controlled from the green area where the instrument panels, remote valve controls and ejector controls are situated. Inactive feeds to the dissolvers, conditioners and mixer-settlers are prepared in and metered into the plant from the green area.

All personnel entering or leaving the amber area must do so through a small change-room where a strict code of house rules is maintained to cover complete change of protective coveralls and overshoes and, on leaving, personal monitoring to ensure that no contamination is taken into the green area. Equipment leaving the amber area is similarly fully monitored in the change-room before being allowed over the barrier, the only exception being the lead-lined highly active sample castles which are monitored for contamination within the amber area before being transferred to the green area via a special hoist.

PLANT OPERATION

A complete reactor charge of 25 elements is received in the plant within a heavily shielded transit flask, each element being contained in a separate channel within the flask. The end assemblies have already been removed from these elements by guillotine by the reactor division concerned, so that only the active constituent, the fuel assembly itself, is delivered to the plant for processing.

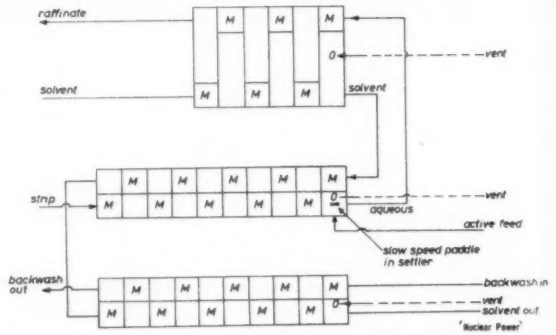
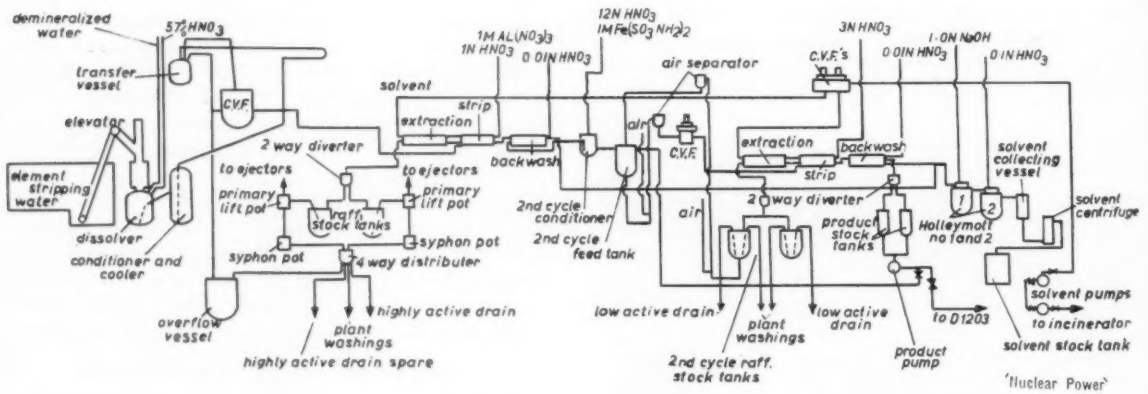


Diagram of the flow through the mixer-settlers (Fig. 3)

Element breakdown

The transit flask is manoeuvred into position within the shielded discharge bay by means of a 25-ton Clyde crane which can traverse the whole length of the amber area side of the plant, and in the discharge position the fuel element channels are horizontal. The flask lid may then be lifted hydraulically and a batch of fuel elements pushed out of their respective channels to fall via a chute into the pond where all the equipment for the breakdown of the elements in preparation for dissolution is installed. The level of the water in the pond is kept at 10 ft 6 in and all handling of the elements is done from above the pond level using long manipulators (Fig. 5).

Separation of the individual plates is achieved by removal of the brazed sides from the fuel assembly. The latter is clamped to a movable table which is driven



Plant flow diagram (Fig. 2)

hydraulically between two circular milling cutters activated by two underwater motors. Some considerable difficulty has been occasionally encountered at this milling stage due to badly squashed fuel assembly extremities caused at the preliminary removal of the end sections by guillotine. This results in part of the sides of the element being unmilled and plate separation then has to be completed as far as possible by a remote chiselling operation. After complete separation, all the plates have to be methodically identified and the top and bottom plain aluminium cover plates discarded. In addition to separating the individual plates, this milling operation removes an appreciable amount of aluminium which would otherwise be an embarrassment at the dissolving stage and also removes silica, present in the braze, which might cause trouble during extraction. After having been sheared to remove some more excess aluminium, the plates are coiled into a shape suitable for charging into the dissolver. Plates which milled satisfactorily are coiled easily but plates weakened during separation after incomplete milling often break and care has to be taken that all the broken pieces are located to avoid a radiation hazard when the pond is emptied. When the dissolver is ready for charging, the coiled plate is transferred to the top of the chute which leads to the dissolver by means of an elevator fitted with one bucket which can hold only one coiled plate. The mechanism of the elevator is coupled to a counter so that when a complete charge has been added to the dissolver the elevator is locked and a dissolver plug automatically drops into position to prevent overcharging. During inactive commissioning, it was found that occasionally plates jammed in the dissolver chute due to faulty plug operation or badly coiled plates and a gamma alarm monitor is installed at the top of the chute to give indication whenever an active plate is still in the chute.

Underwater adjustable lighting is installed in the pond but due to fine particles of disturbed rust and alumina in suspension, the visibility within the pond often deteriorates rapidly as the breakdown operations proceed. A continuous water overflow from the pond reduces the rate of this deterioration. Good visibility is almost essential in order to ensure that the fuel assembly is properly oriented on the milling machine table and in the subsequent separation and identification of the plates.

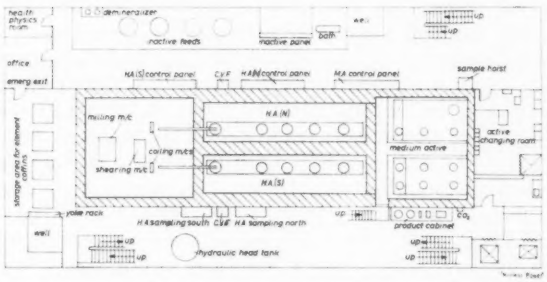
The swarf and scrap alumina which are formed during the milling and shearing operations are collected in a cast iron disposal flask mounted on a trolley adjacent to the milling machine table. When full, this is lifted out of the pond and the contents dispatched to permanent highly active storage. High radiation from this flask is occasionally encountered, resulting from slight cuts into the uranium-aluminium alloy core plate itself during milling and shearing. It has been found that the radiation emanating from the flask is appreciably reduced by omitting shearing, an operation which is not absolutely essential.

There is no radiation hazard at the working positions above the pond but on completion of a processing run the water is discharged to low active drain and the whole pond area cleared of remaining active swarf. This is done using the remote handling tools initially but the final cleaning operations are done by operators within the pond itself and strict control on personal radiation doses received and on preventing spread of contamination is necessary whilst this is done. All the equipment is then checked and any maintenance work found necessary carried out in preparation for the next run.

Sampling

The highly active sampling system is schematically represented in Fig. 7. Although the volume of sample taken is only a few millilitres it is essential that all the operations are carried out behind shielding in view of the very high specific activity. By application of a vacuum bottle to start a circulating siphon in the circuit there is no possibility of active liquor being lifted out of the shielded cell. When the siphon breaks a small volume of liquor is left in the sample pocket and this is then sucked out into a sample bottle which has been previously evacuated and which is subsequently handled in a lead-lined container during the transfer to the analytical laboratories.

The main process vessels sampled in this manner are the



Horizontal section of the plant through the shielded cells and working area (Fig. 4)

first cycle conditioner and first cycle raffinate tanks. The conditioner liquor comprises the first cycle active feed so that accurate analysis is essential at this point both for uranium accounting and for criticality control on the batch dissolution process. To ensure that the sample obtained is representative of the liquor being sampled it has been found necessary to adopt a sampling technique which thoroughly flushes the whole system of all liquor remaining in the system from the previous sampling operation.

In view of the highly viscous nature of the liquor being sampled this flushing operation has to be repeated several times and the overall time cycle of a highly active sampling operation is well over one hour.

Care has to be taken in the manipulation of the bottle within the sampling head (see Fig. 8) and in the dropping of the bottle into the shielded container within the head. It is possible for a bottle to be badly damaged during these operations by poor manipulation and serious contamination could result. Therefore, immediately the container is removed from the sampling head it is thoroughly monitored for contamination.

Sampling of the process vessels within the medium active cell is much easier and is done with no shielding. Liquor from the vessels, after thorough sparging, is sucked into a small glass vessel and a sample taken by the usual evacuated bottle technique, the remainder being allowed to run back into the vessel. Again, precautions are necessary to ensure that the sample obtained is representative but on

this relatively simple system this offers little difficulty. Regular eight-hourly samples are taken from all the medium active sample points for plant control, uranium balance, and overall plant accounting.

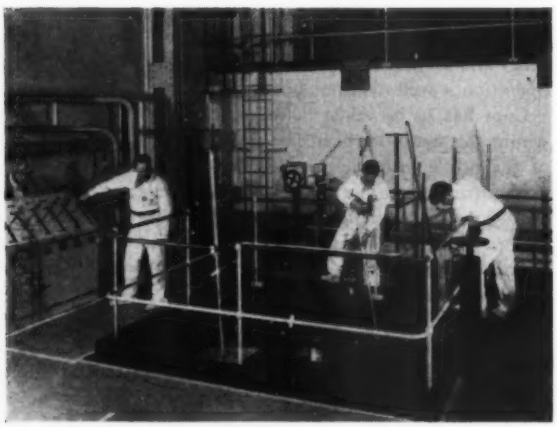
Some mechanical features

With liquors of such high radioactivity content, pumps could not, of course, be used for transfer from one vessel to another in view of maintenance difficulties and this is therefore done by ejectors. Most of the highly active liquor transfers are effected by air ejectors through a vacuum lift vessel coupled to a safety vessel to ensure that no active liquor can be drawn outside the biological shield. The air ejectors are situated within a shielded bulge above the active cells and over two years of operation the radiation from the ejectors has become appreciable due to mist drawn up from the active liquor. Steam and water ejectors are used for medium active liquor transfers.

The extractor mixer contents are stirred mechanically by long-shafted paddle stirrers housed within the shield block immediately above the mixer-settlers and driven by a set of three ½ h.p. electric motors for each cycle. A tachometer fitted to the end of the driving shaft indicates the speed of rotation of the stirrers and this stirring speed, found to be important in the operation of the mixer-settlers, is adjusted by rheostat over the required range.

With the exception of the first cycle active feed, all the feeds to the mixer-settlers are metered using a constant volume feeder of the type illustrated in Fig. 9. The length of stroke is adjusted by means of a locking unit on the piston shaft and, in general, consistent feedrates have been maintained over long periods using this equipment although frequent checks on the volumes of liquor fed from the respective tanks are made as confirmation. The first cycle active feeder is situated within the highly active cell and is a rotor-type to obviate the possibility of mechanical breakdown.

The height of the building is such that barometric lutes cannot be used to seal the outlets from the two vacuum lift vessels in the highly active cell and angle valves actuated by a compressed air cylinder are used where the conventional gland is replaced by a bellows assembly. These valves have operated well and maintenance work has been necessary on only one occasion during active operation.



Operators using long manipulators to handle elements in the pond (Fig. 5)

General view of a medium active cell (Fig. 6)

DISSOLVER AND EXTRACTOR PERFORMANCE

Dissolver

The coiled uranium bearing plates are dissolved in a stainless steel pot dissolver fitted with a triple surface reflux condenser (see Fig. 10).

After some initial amendments to the conditions recommended from the laboratory and pilot plant work to cater for the characteristics of the installed equipment, several hundred active batches have been dissolved successfully to date. On very few occasions has the acid deficiency of the dissolver product been out with specification.

Use of an inactive dissolver to prepare acid deficient aluminium nitrate solutions for run-up and run-down of the solvent extraction plant led to the discovery that dissolution of aluminium caused severe corrosion of stainless steel when the two metals were in contact due to the production of hydrogen which destroyed the protective oxide film. Because of this, the spare Highly Active cell is being fitted with a dissolver fabricated from titanium and operations will be transferred to this cell when installation is complete.

Mixer-settler

First cycle. The flowsheet for the first cycle solvent extraction process is based upon the anion deficient dissolver solution mentioned earlier and utilizes aluminium nitrate as a salting out agent. Consequently, the uranium partition coefficient between acid deficient aluminium nitrate solution and 5% TBP/OK is very high and only 3.5 theoretical extraction stages are required for 99.99% uranium extraction. In fact, 6 stages are available in the plant and in consequence some margin of safety is available and extraction efficiency has been excellent. The chemistry of the solvent extraction process has been discussed in detail elsewhere (*1*) and will not be further discussed here.

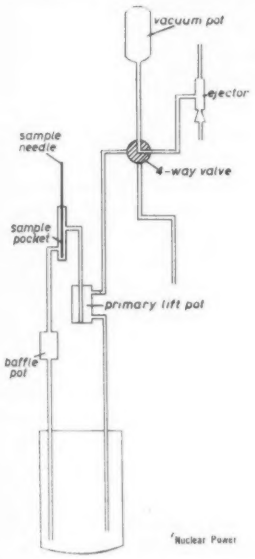
During inactive commissioning of the plant liquor levels in excess of the normal operating level of 4 in were experienced at certain flow rates. Later, after active operation was

commenced, high liquid levels were found intermittently at normal flowsheet flowrates. The effects of these high levels were two-fold:

(1) If allowed to persist, the levels spread throughout the extractor box until solvent and uranium were lost to the aqueous raffinate tanks via the vent pipe on the adjustable weir.

(2) If flows were stopped until the level subsided, on re-starting the feeds fission product activity retention rose in the solvent phase and consequently in the aqueous backwash phase.

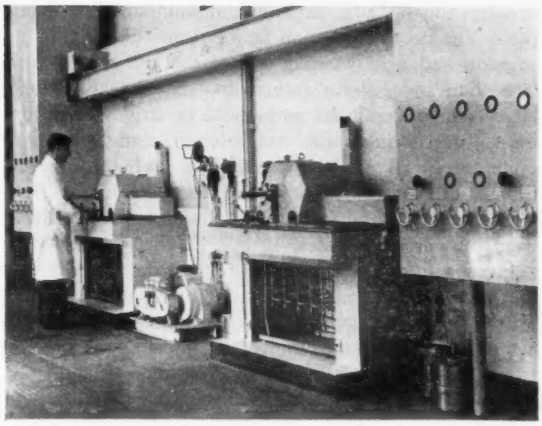
Attempts to operate without venting the aqueous weir were unsuccessful and increases in the recommended stirrer speeds were found to be beneficial. However, as the burn-up of fissile material in the elements processed has increased and the equipment has become more contaminated, the incidence of high levels has increased. A thermistor probe was developed and later made adjustable which gave warning of a rise in liquor levels and three of these units were fitted into the extractor box in the second, fourth and last settling stages (see Fig. 3). Operational techniques were evolved and are being developed to reduce



Schematic of the highly active sampling system (Fig. 7)

the frequency of high levels and to minimize the effects. Loss of fissile materials by the mechanism described in (1) above is avoided at the expense of increased activity retention as mentioned in (2). The cause of the high levels is not definitely known though it is suspected that the relatively slow flow of a highly viscous solution containing a large percentage of hydrated fission products through a $\frac{5}{8}$ in bore pipe baffled at one end causes sedimentation and restriction to the aqueous flow. This causes aqueous build-up in the strip box and, in consequence, solvent build-up and a high total level occur in the extractor.

An overall decontamination factor for γ-activity of 2×10^7 is demanded so that if any reduction in first cycle decontamination occurs then a greater requirement is put on the performance of the second cycle. Since the second cycle sample points are of low active design without biological shielding any breakthrough of fission products to the second cycle also creates a radiation hazard to the



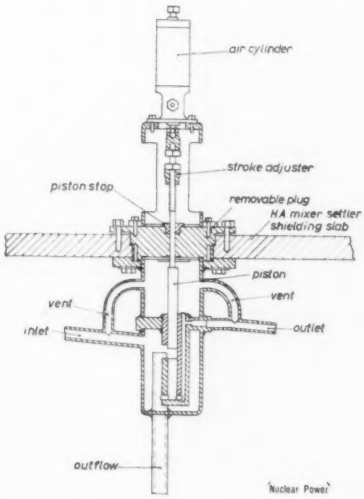
Operator manipulating a bottle within the sampling head; care must be taken as serious contamination could result from the bottle being badly damaged (Fig. 8)

operators during sampling and other handling operations.

Solvent washing. The original solvent system installed in the plant was designed to meter solvent into the first and second cycle extractors from a common stock tank. After backwashing, the two streams recombined and passed through a common wash system to the stock tank. As the specific activity of the first cycle active feed increased, retention of fission products (mainly zirconium and ruthenium) in the first cycle solvent also rose until it was found necessary to separate the first and second cycle feed and wash systems completely to maintain the purity of the aqueous product solution. The reason for this modification is that a small fraction of the zirconium retained in the solvent partitions into the aqueous phase in the second cycle backwash mixer settler and raises the fission product content of the product above the specification limit.

As an additional safeguard a column containing finely divided silica gel is kept in readiness so that the product stream can be diverted through it. A further decontamination factor of 7–10 can be obtained for zirconium by use of the column.

Under normal operating conditions with active feed of high specific activity the solvent leaving the first cycle



Most feeds to the mixer-settlers are metered by a constant volume feeder of this type (Fig. 9)

contains roughly 80% zirconium-niobium and 20% ruthenium. The decontamination factors achieved by inter-cycle alkaline and acid washing are of the order of 7–10 for zirconium and 3–4 for ruthenium. These factors are not large enough to prevent an increase in activity retention in the solvent during a run and between campaigns the first cycle solvent is also subjected to a prolonged recycling through the wash system which achieves a further decontamination of 40–60 for zirconium and 4–8 for ruthenium over four complete passes.

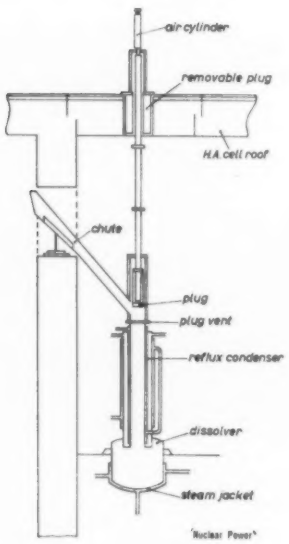
Investigations are in progress both in the laboratory and the plant into alternative wash solutions and it has been proved that small concentrations of additives in the dilute acid wash results in the removal of almost all the zirconium from the solvent. Only a small proportion of the ruthenium is removed by this method and the most successful techniques for ruthenium decontamination appear to involve precipitating solids such as manganese dioxide upon which the ruthenium is absorbed. These techniques are not immediately applicable to the plant and research is continuing into alternatives for ruthenium removal.

Second cycle. The second cycle process is based upon an acid flowsheet and the safety margins both for extraction efficiency and decontamination of the uranium are not so great as those in the first cycle. 9.5 theoretical stages are required for 99.99% extraction efficiency and 10 are actually provided. No real difficulty has been experienced in maintaining extraction efficiency and uranium recovery has been excellent during the life of the plant.

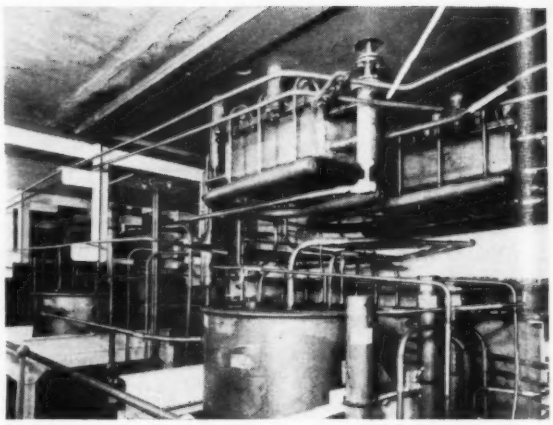
The relatively low specific activity of the second cycle active feed ensures that no difficulties are experienced with retention of activity in the second cycle solvent.

CRITICALITY AND RADIATION SAFETY

With the exception of the extractor section, none of the vessels in the plant is geometrically limited in terms of criticality and therefore criticality control is achieved by mass limitation. The possibility of double batching is not catered for in the first cycle (dissolver excepted) due to the concentration of the uranium solution being well below the 'infinite sea' concentration. In the later stages where the concentration is higher, a mass limit on the medium active cell is imposed and strict control exercised on the distribution of fissile material within the cell. Frequent uranium balances across the plant are made so that it is not possible for uranium to be diverted from the main process stream in any unforeseen manner without being discovered.



Stainless steel pot dissolver fitted with a triple surface reflux condenser; the dissolver chute and plug are shown (Fig. 10)



Some of the equipment within a highly active cell, including mixer-settlers. White line indicates an adjustable aqueous weir. (Fig. 11)

Conditions in the dissolver are such that this has to be considered separately. It is possible during an intermediate stage of partial dissolution for the concentration of uranium to exceed the minimum critical concentration so that a higher safety factor is introduced to cater for the possibility of double batching. In addition, an elaborate channel key system is imposed to limit the number of fuel elements that may be discharged from the transit flask at any one time and the interlocking mechanism on the plate charging elevator to the dissolver is a further safeguard. The possible hold-up of uranium in the dissolver is estimated after each dissolution using the reactor division burn-up figures for the amount of uranium left in each element.

In spite of the design and operational precautions taken, extensive instrumentation to detect a criticality incident immediately has been installed and regular mock alarms and evacuation practices are held to ensure that all personnel react appropriately.

On the general radiation safety aspects, regular contamination and radiation surveys and air sampling are carried out throughout the working areas and the results are reported to the plant supervisor so that the necessary action may be taken with the minimum delay.

SUMMARY

The chemical plant for the reprocessing of the enriched uranium-aluminium alloy fuel elements from the various Materials Testing Reactors has been operated for three years. Good uranium recovery and satisfactory decontamination from fission product activity have been achieved despite difficulties encountered in mixer-settler operation during the reprocessing of fuel elements of very high burn-up.

Reference

1. United Nations Peaceful Uses of Atomic Energy. Proceedings of the Second International Conference, Geneva, September, 1958. Volume 17, p.25.

Cross Section by GRACCHUS

PART OF the reason behind the formation of Nuclear Developments Limited by ICI, Rolls-Royce and Rio Tinto was the 1959 report by the Select Committee on Estimates. This advocated that more work should be turned over by the AEA to private concerns, particularly in the fuel element field. At about the same time as Nuclear Developments Ltd was formed, a similar move was taking place in the USA. The United Nuclear Corporation was founded by Olin Mathieson Chemical Corporation, Mallinckrodt Chemical Works (Mallinckrodt have links with Rio Tinto through Nukem in Germany) and Nuclear Development Corporation of America. This major integrated company will place a notable emphasis on reprocessing spent fuel. Another consideration, and here there is an echo in the formation of the UK firm, was the US Government expressed desire to induce private industry to enter areas which have been mainly the province of the Government.

ONE CAN sympathize with the General Electric Company and its need to make changes in the company's administrative structure. Its troubles have been experienced, though to a lesser degree, by other heavy electrical manufacturers; the company's finances have been under strain for some time and the group is reported to be using about £16 million of overdrafts. Changes in the administration have taken place and having formed a new management committee, the company plans to strengthen the management still further. These factors and the falling through of the English Electric merger made it almost certain that some streamlining would take place. What is surprising is the way in which cuts have fallen on some sections of the staff—the public relations and publicity departments have been drastically pruned. The manner in which the blow was delivered, with virtually no softening, was hardly calculated to create a good impression. The company has built up a favourable public image and it is a pity that it should have, in one stroke, jeopardized much of the good publicity work done in the past.

THERE WERE some reassuring words for the British nuclear industry from Sir Roger Makins when he attended the recent Gauge and Tool Makers' Association luncheon. He said he knew there was a feeling of disappointment in some parts of industry about atomic energy work. Certainly 'the saguine expectations of five years ago have been disappointed both at home and abroad', he added. 'But I venture to say that British industry will, in due course, reap substantial benefits from its early and practical experience in this new technology.' On the face of it, the speech was reassuring. I would like to see something substantial and concrete follow it. True, there is a renewed interest in the building of nuclear power stations; Pakistan is the latest to show an interest; Mitchell Engineering are working on a design study contract for an Italian firm; both English Electric and GEC are working for the Indian tender; Brazil is still a possibility as is Spain and the rumour that Italy is in the market for another large power station has persisted from the end of last year. But one has the feeling that the bread and butter jobs will not be coming to industry except at the expense of the AEA. If more development contracts are put out by the AEA, the Authority will find themselves overstaffed. But perhaps one should go along with Sir Roger's prediction that the present mood of uncertainty about nuclear power prospects would, as experience of large power reactors accumulated, give way to renewed confidence in its future.

I liked the reply to Sir Roger given by Mr G. P. Barrott, the chairman of the Association, who referred to the manipulator design activities to which the tool makers had made a substantial contribution. There was no doubt in his mind, he said, that they were the 'master slaves'.

He further defined 'High Activity' as that occurring when Association members received contracts from the Atomic Energy Authority and 'Frozen Rigidity' as the state which resulted when the cost of the job was given—often this came above contract estimates.

THE QUIET meetings arranged by the Federation of British Industries on whether or not to set up a UK Atomic Forum and join Foratom, have aroused much attention overseas. The Canadians, who recently set up their own Forum, are anxious to keep in touch while Foratom, at its last meeting, pointed out that it had been in close communication with Great Britain. Three UK meetings have been held so far. The first exploratory meeting was on March 3 followed by another on April 11 when it was decided to set up a working party. This reported back to the FBI on May 10.

On record

'. . . We see no place for rugged individualism, which is fine for the individual but intolerably rugged for everyone else with whom he must work. We are instead trying to make a place where individual ruggedness and persistence in conquering technology's commanding heights is appreciated; we want to make a status symbol of intellectual accomplishment.'

William Bergen, President, The Martin Company of the USA, at the annual meeting.

'. . . In my view, the first two years of undergraduate training of an engineer should be devoted to engineering science embodying the scientific principles which underly his technology. Only after this is inculated should he begin to specialize . . . Even then we should take note of the fact that technology is tending to become more and more interdisciplinary in character.'

The Trueman Wood Lecture 'The Training of Scientists and Engineers for Industry', by Sir John Cockroft, at The Royal Society of Arts.

Government agreements with 41 countries have paved the way for US nuclear firms

The US Nuclear Export Drive

by SIDNEY HOLLANDS, B.Com., News Editor, Nuclear Power.

AMERICAN companies who have established links and subsidiaries in Europe are not only finding their capital and know-how welcome but are beginning to realise that a splendid opportunity exists for profitable interchange of know-how. Techniques, processes and inventions discovered and developed by European associates can be transported to the USA; investment in Europe provides an excellent method of two-way communication that will keep a company in touch with profitable technical developments and potential markets.

To be added to these reasons is the general realisation that world markets are growing faster than the vast US domestic market and that American exports can compete in overseas countries. The leeway that US firms have yet to make up in the export field can be gauged by comparing the total of US exports in 1959 which amounted to 3·6% of the country's gross national product with the 16·7% of West Germany in the same year.

Furthermore, because of the growth of tariffs, i.e. the Common Market and the European Free Trade Association, US firms are establishing themselves on the right side of these tariff barriers. This they did in 1960 to the extent of investing $580 million in new plant and equipment in Europe. An additional bonus is a reverse flow of exports as these firms found that with cheaper European labour, it was profitable to have certain lines made in Europe by their subsidiaries and then exported to the United States.

THE NUCLEAR PATTERN

In the nuclear field, this pattern has been followed to a large extent. Since 1953, US firms have been producing 'experimental power demonstrations' and the American nuclear programme throughout has been characterised by the great number of different types of reactors with variations in fuel enrichment, canning, moderators and coolants. As the US Atomic Energy Commission points out in its 1960 annual report, 'As of June 30, 1960, there were 66 civilian and military reactor projects under active design or construction for use in the United States (exclusive of naval propulsion, aircraft and space reactors) . . .'

> Travelling vice-presidents of American firms, tying-up policy with subsidiaries and keeping a check on links with European companies have now become a common sight in western Europe. They typify the depth of penetration made by US firms striving to increase their export markets and their investments in Europe

As a result, industry in the United States has gained experience over a wide range of reactor types. America has, for some time, been in a strong position in export markets not only from accumulated know-how but also from her possession of large supplies of uranium both enriched and natural, and also heavy water.

In addition to this basic framework, US firms have been helped by bilateral agreements, sometimes called Agreements for Co-operation, under which the US agrees to supply enough nuclear materials to fuel various types of reactors, in addition to quantities of thorium, uranium, heavy water and technical and engineering information. A total of 41 of these agreements (these do not include the ones with Euratom and the International Atomic Energy Agency) have been negotiated by the US with 39 countries, including two with Switzerland. Of these agreements, 14 have been for power reactors and 27 for research or training reactors. This has made the US the

SOME MAJOR US—EUROPEAN COMPANY LINKS

	FRANCE	GERMANY	ITALY	UNITED KINGDOM
ATOMICS INTERNATIONAL	Dynatom	Interatom	Montecatini	English Electric
BABCOCK & WILCOX	Indatom French B&W	German B&W	CRDA	
GENERAL ELECTRIC	Alsthom	AEG		
GENERAL DYNAMICS		Gutehoff. Sterkrade		Vickers
WESTINGHOUSE	Framatom	Siemens	Fiat	Rolls Royce (Dreadnought)
MALLINCRODT		Nukem	Italatom	

Atomics International also have links with ASEA of Sweden; General Electric with Suisatom, Switzerland and Westinghouse with ACEC of Belgium. AMF Atomics and Alliss Chalmers have major links in the UK and France respectively.

leader in the export of reactors. During 1960, for instance, eight United States manufactured research, training and test reactors went into operation in foreign countries, bringing the total to 27. An additional 17 research, training and test reactors were being built abroad by US companies as of November 30, 1960, and seven more were planned for construction.

Of power reactors, one was built in West Germany (Kahl) and five others are planned for construction abroad or were under construction in 1960.

THE VALUE OF RESEARCH REACTORS

However, despite the large sale of research reactors, most American manufacturers agree that there is little money to be made in their construction. Their value, according to one British executive, is that they represent a major prestige item and open up channels for negotiation for advanced types of facilities. 'The Americans have long recognised that most of the countries in the world will ultimately have research and training reactors,' he added. 'The value of a Made in USA imprint is undeniable. These reactors also mean that technicians become trained in American ideas and with US equipment and when larger facilities are to be built it is only natural that they should show a bias towards American equipment and standards that they know. There is no substitute for experience and actual working knowledge of the type of facility that will be installed.'

Backing up the installation of nuclear facilities in overseas countries are the training programmes run by the Atomic Energy Commission and private firms. For instance, since 1955, 416 foreign students from 45 countries attended nuclear science and engineering courses at Argonne National Laboratory and over 400 students from 56 countries have received training in radioisotope techniques at Oak Ridge since 1947.

In addition to these direct aids to 'have-not' nations to help them undertake an effective nuclear energy programme, US firms have provided access to scientific and engineering information. They have also aided firms in these nations in building so that they have actual experience in the design, construction and operation of nuclear facilities.

This latter requirement is being met to a large degree by licensing arrangements or jointly-owned subsidiary companies. Most of the major US firms, for instance, have such links on the Continent. Atomics International is a leading example with links in France, Germany, Italy, the United Kingdom and Sweden. Westinghouse are in a similar position though their link with the United Kingdom is for a pressurized water reactor for the submarine Dreadnought.

SEVERE STRUGGLE

It is against this background that British and possibly French firms have to compete for the export market which at present is confined to European countries, Japan and the Indian sub-continent. (The Soviet Union as a supplier is not considered here as she does not yet compete for overseas contracts). There is no doubt that American competition will be fierce—already in some instances the battle for design contracts has been so severe as to justify the charge of unfair. The tremendous effort put into the selling of power reactors over the last two years, though out of proportion to the number sold, is likely to continue on the same scale with perhaps German and Scandinavian companies entering the field at a later date.

One ace the Americans still hold is the research effort they have put, and are putting, into the development of small reactors. Here again, while there is no immediate market for a small reactor, their experience will provide a highly significant advantage for future export markets. This lack of development by the UK may well be regretted though there are indications that preliminary steps are being taken to enable Britain to meet the demand for small reactors.

Of equal importance is the need to recognise that it is not only the competitive ability of firms that will determine the sales of reactors and nuclear equipment. International politics alters the purely commercial aspects of selling, with sales being dependent on agreements that only a Government can make.

COMMONWEALTH GROUPING

Some more imaginative official UK effort has to be made—perhaps on the lines of ex-President Eisenhower's 'Atoms for Peace' programme. So far, the Government has only taken part in one significant project—the Baghdad Pact Nuclear Centre for the application of radioisotopes to agriculture, biology and medicine. The idea of a Commonwealth grouping in nuclear energy has been stressed before and should be revived and seriously examined both as a means of developing future markets and as a means of pooling financial and manpower resources and developing new reactor concepts.

Research and Training Reactors
Built or being built by US firms
in overseas countries

ALLIS-CHALMERS

Ispra, ITALY
Petten, NETHERLANDS
Studsvik, SWEDEN

AMF ATOMICS

Munich, W. GERMANY
Delft, NETHERLANDS
Ontario, CANADA
Seibersdorf, AUSTRIA
Lisbon, PORTUGAL
Athens, GREECE
Rehovoth, ISRAEL
Tokai-Mura, JAPAN
Istanbul, TURKEY
Teheran, IRAN
Turin, ITALY

ATOMICS INTERNATIONAL

Ris, DENMARK
Frankfurt, W. GERMANY
Tokai-Mura, JAPAN
Berlin, W. GERMANY
Milan, ITALY

GENERAL ATOMIC

Belo Horizonte, BRAZIL
Leopoldville, CONGO
Rome, ITALY
Yokahama, JAPAN
Seoul, KOREA
Helsinki, FINLAND
Seibersdorf, AUSTRIA
Dalat, VIETNAM
Bandung, INDONESIA
Belgrade, YUGOSLAVIA

GENERAL ELECTRIC

Caracas, VENEZUELA
Hainchu, FORMOSA
Madrid, SPAIN
Quezon City, PHILIPPINES

This table excludes reactors built or being built by Babcock & Wilcox (2), Curtiss-Wright (1), and Foster Wheeler (1). The main companies building power reactors abroad are General Electric (Kahl, Senn, Tokai Mura) and Westinghouse (Mol and Chooz).

Points from Papers

reports, meetings, conferences

TURBINE-REACTOR CONTROL

To achieve maximum system economy, nuclear plant needs to be capable of controlled load generation to match generation-to-customer load. With this in mind an electronic system has been installed in the Sodium Reactor Experiment. During experimental tests the SRE plant control system was used to change the thermal power level with electrical power requirements at a rate of 20%/min. The plant control system was able to maintain a constant steam pressure and temperature gradient across the reactor with rapidly changing electrical power, sodium flow and reactor power.

These initial tests have shown that the SRE is able to follow load demand during rapid load changes and that this has not had adverse effects on the heat transfer characteristics and reactor stability. The integrated plant control will be placed in operation after the SRE second fuel loading and zero-power tests have been concluded. This should be finished this year.

An integrated turbine-reactor control system for the sodium reactor experiment. J. R. Hall. Atomics International and F. C. Six, Leeds and Northrup Co. **Report AI-6121.** 16 pp. Presented at the American Power Conference, Chicago, March 1961. Copies available from *Nuclear Power*.

BOILER CIRCULATION THEORY

This research project aimed at establishing experimental data concerning flow conditions and pressure drop of high pressure steam-water mixtures flowing along heated and unheated pipes in both the vertical and horizontal positions. The paper is in three parts. The first describes the construction and operation of the experimental plant; the second analyses the results obtained by use of gamma-ray equipment of the apparent density of the fluid mixture and consequently the velocities of the two phases and the third presents an analysis of the pressure drop measurements. The authors conclude that for experimental pressure drops at 2100 lbf/in^{2}a the results were close to those predicted by homogeneous theory. For horizontal pipes at lower pressures, the theory gave a closer prediction for heated than for unheated pipes. This is due to the opposing effects of two-phase conditions on the frictional and acceleration pressure drops in the heated pipes. Experimental pressure drops for vertical pipes at the lower pressures were greater than those predicted by homogeneous theory. Closer prediction can be obtained by using a slip correction factor. It is not expected that this work was of the kind that produces revolutionary changes of design. The results do, however, provide a valuable addition to the knowledge of the processes occurring in the steam raising tubes of high pressure boilers.

Experimental study of the flow conditions and pressure drop of steam-water mixtures at high pressures in heated and unheated tubes. R. W. Haywood, G. A. Knights, G. E. Middleton, and J. R. S. Thom. **Reprint 37/60.** 60 pp. Available from the Institution of Mechanical Engineers.

ECONOMICS

The doubling time of electricity demand in the underdeveloped parts of the world—seven years—is faster than in industrial countries and it is important that this demand be met as economically and as efficiently as possible. Much of the early optimism about the ability of nuclear reactors to supply cheap power has now faded. This paper critically appraises the economics of small nuclear power stations in the context of the conditions likely to prevail in these less-developed countries.

Nuclear reactors No. 5. The economic of small power reactors. Shell International Petroleum Co. **Report A5-61.** 21 pp. Copies available from *Nuclear Power*.

FALLOUT

Results of a radiation survey carried out around Harwell during 1958 and 1959 show that there was no variation in dose rate due to deposition of radioactivity from the AERE. Maximum levels were reached in May/June 1959 and these were due to fission product deposition from nuclear explosions.

District gamma radiation survey around AERE Harwell, results for 1958 and 1959. A. Morgan. AERE Harwell. **Report AERE M 71.** 8 pp. Available from HMSO *1s. 9d.*

DECONTAMINATION FACTORS

Experiments at Harwell have shown that the ruthenium decontamination factor can be improved by treating the uranium stream from an active TBP cycle with hydrazine at 70–90°C for 1–2 h before the uranium purification cycle.

Pretreatment with hydrazine prior to the uranium purification cycle of a TBP process. A. G. Wain, R. J. W. Streeton, E. N. Jenkins, J. M. Fletcher and P. M. G. Brown. AERE Harwell. **Report AERE R 3509.** 14 pp. Available from HMSO *2s. 6d.*

RHENIUM THERMOCOUPLES

Certain disadvantages in the use of pure tungsten/rhenium thermocouples, primarily the limitation of use to 4000°F, for high temperature work has led to the investigation of the thermoelectric properties of tungsten based alloys containing up to 30%-wt of rhenium. This has been done on the suggestion that there might be a tungsten/rhenium system analogous to the platinum/rhodium alloy system. The three years work at GE-ANPD resulted in the development of a thermocouple consisting of tungsten/tungsten-26% rhenium has been shown to have a high thermoelectric power to 5200°F; a high melting point, probably above 5400°F; to be chemically stable at high temperatures in protective atmospheres; low component materials vapour pressures; ease of fabrication; and relatively low cost compared with noble metals and unalloyed rhenium.

Thermocouples for 5000°F using rhenium alloys. J. C. Lachman and J. A. McGurty. General Electric, Aircraft Nuclear Propulsion Department. 24 pp. Paper presented to The Electrochemical Society Symposium on Rhenium, May, 1960. Copies available from *Nuclear Power*.

GAS DENSITY MEASUREMENTS

This report sets out the engineering data for beta-ray gauges or other electron probes working on the attenuation principle for measuring gas densities. The author shows that a density range from below 10^{-5} to over 1 g/cm^2 can be properly covered by the selection of a suitable attenuation coefficient of the electron energy. He also shows that for every attenuation coefficient there is a density range of about 10 : 1 over which the accuracy of the gauge is high and nearly constant. The report includes graphs showing the ranges and attenuation coefficients for various beta sources.

Beta-ray gauges for gas density measurements. B. W. Schumacher. Dept. of Physics, Ontario Research Foundation. **Report ORF PRR 6001.** 24 pp. Available from Ontario Research Foundation $2.50.

New Reports

Radiation preservation of selected fruits and vegetables. USAEC. **Report SRIA-30.** Available from OTS $3.00 or from depository library.

The inspection of pressure components intended for nuclear service. J. A. Frew. Lloyd's Register of Shipping. In *The British Journal of Non-Destructive Testing*. Vol. 3, No. 1, March, 1961.

Strontium 90 in milk and agricultural materials in the United Kingdom 1959-1960. Agricultural Research Council Radiobiological Laboratory. **Report No. 4.** 81 pp. Available from HMSO *5s.*

Behaviour of metallic thick-walled cylindrical vessels or tubes subject to high internal or external pressures at elevated temperatures. A. E. Johnson, J. Henderson and B. Khan. **Paper 38/60.** 29 pp. Available from the Institution of Mechanical Engineers.

Atomic energy's contribution to non-destructive testing. P. C. Aebersold and O. M. Bizzell. Office of Isotopes Development. USAEC. 12 pp. Presented at the Society for Nondestructive Testing Convention, Los Angeles, March, 1961. Available from OTS or depository library.

Strontium studies. Katherine Williams. AERE Harwell. **Report AERE R3423.** 53 pp (with bibliography). Available from HMSO *8s.*

A survey of the plutonium spectra in the 7000–10,000 Å region. L. Bovey, M. C. J. Barker and A. Ridgley. AERE Harwell. **Report AERE R3515.** 11 pp. Available from HMSO *2s. 6d.*

Our concluding article emphasizes that several years' work has been needed before 'experiments can be mounted with a high probability of success'

Irradiation techniques for fissile materials—6

by O. S. PLAIL, A.M.I.Mech.E., Group Leader, Irradiation Branch, Metallurgy Division, AERE, Harwell

PREVIOUS ARTICLES in this series have described various aspects of the irradiation techniques used at AERE Harwell to investigate the behaviour of fissile materials under neutron irradiation. The results obtained have been discussed by Pugh (*1*) Greenwood (*2, 3*) and others, but during the course of the experiments a considerable amount of experience has been acquired in what may be described as 'Irradiation Philosophy' and it is hoped in this final article to summarize it and emphasize those aspects which are regarded as important.

One fact that is probably not fully appreciated is the very high cost in labour and equipment of most irradiation experiments quite apart from the reactor costs which are in themselves considerable; this fact controls much of the 'philosophy' discussed below.

WORKING METHOD

Because irradiation experiments are frequently complicated and involve considerable engineering effort it is not unusual for the sponsor of an experiment to prepare a technical specification against which a project engineer will design a rig and organize a large part of the experimental programme. In the work discussed in this series, however, the same people who have had the responsibility for planning the scientific aspects of the experiments have worked in close collaboration with the design engineers and become deeply involved in the development of new techniques using their own laboratory and workshop for much of the work, including prototype rig manufacture, the final detailed design and manufacture being undertaken by the engineering divisions. Also, again in close collaboration with the Reactor Engineering teams, the experimental staff have carried out a large amount of pre-irradiation testing and commissioning, and have also played a big part in installing the apparatus in the reactor.

This method of working has evolved directly from the early Windscale experiments and, in practice, has worked very well; it has not been confined to the actual irradiation rig aspects but has also been applied to post-irradiation techniques. New designs of shielded facilities have usually involved the experimental staff on considerable mock-up and development work again in close liaison with the designers which has then been followed by detailed design and manufacture by the Engineering Divisions, final commissioning being undertaken as a collaborative effort.

It is interesting to comment on the part that the development workship has played in this. A considerable number of ideas have come from this shop and frequently it has been found that the mechanics can make a very large contribution to the practical development and manufacturing techniques.

The main advantages of this method of working are three-fold. Firstly, this close collaborative effort between experimental staff, design engineers and workshop for the preliminary assessment and the continual development results in final designs in which reasonable compromises are reached between the possible conflicting requirements of experimental needs, engineering design, in-pile operation and manufacturing difficulties. Secondly the use of laboratory-type experiments both in and out-of-pile helps in many of the design problems and gives the experimenter a much clearer understanding of the conditions existing in the rig.

Thirdly, by involving the experimental and scientific staff in many of the practical aspects of the work, a block of experience has become available which is of very great use in the detailed planning of the actual experiments both in-pile and in the post-irradiation examination. Thus, because the same team of experimentalists have been responsible for much of the detailed experimental programme, it has therefore been possible to formulate experiments which are within the capabilities of the equipment and this intimate knowledge of the techniques has frequently obviated some of the pitfalls of over specification which are otherwise likely to occur. There is a very real danger of experimental staff insisting on a rigid and unrealistic specification in an attempt to achieve ideal conditions. Experience has shown that frequently the acceptance of slightly less stringent conditions enables the work to proceed more rapidly.

The close connection of the scientific staff with the practical aspects of the work is also extended to the detailed post-irradiation examination. The responsibility for an experiment obviously lies with the sponsor. Although the personnel operating the remote handling building will give a service and carry out well defined measurements, e.g. density determinations, dimensional checks etc., the sponsor is encouraged to come into the remote handling building as much as possible to supervise the work and check results. In the case of examinations such as post-irradiation metallography, the sponsor will in fact operate the metallograph himself. It is considered that there are inherent dangers in a system which collects post-irradiation data and passes this back to the sponsor and it is therefore

very important that he should be intimately acquainted with the post-irradiation examination because he alone will have an overall appreciation of the complete experiment.

ECONOMY OF EQUIPMENT

The article in the January issue of *Nuclear Power* discussed the design of the rigs used for irradiations in DIDO and PLUTO.

The basic simplicity of design and their inherent safety has led to their widespread use not only at AERE but in other materials testing reactors both in the UK and Europe. They have proved to be very reliable in service and very few have been prematurely removed from the reactor due to faults.

As was pointed out in the earlier articles they can be used for a variety of experiments and this flexibility is a most important point. Whenever a new experiment is proposed it is carefully examined to see whether it can be fitted into one of the existing rigs, if necessary making alterations to accommodate it. The alternative is to design a new rig for each experiment and experience has shown that this can be a fairly lengthy and expensive business. There is therefore, considerable incentive to use these existing designs and in fact they are being used for a variety of experiments, ranging from gas release measurements from UO_2 under irradiation to small scale fuel element tests.

Although there is no doubt that the rigs as they stand could be improved, there is a very real danger that perfection in design can become an end in itself. It is essential that the main function of the irradiation experiments i.e., to obtain a better understanding of irradiation effects, should be kept very much in mind. Therefore new developments must be carefully considered in relation to the effort required and the resulting advantages. This philosophy also applies to remote handling. Typical of this attitude is the decision recently taken to install a further remote metallographic suite; to save expense and design time an almost exact copy of the one described in the last article is being installed.

REMOTE HANDLING

Considerable changes have come about in the post-irradiation examination of the fissile samples (see *Nuclear Power*, May, pp. 82-86). The use of the lead shielded boxes for this work has been largely justified but their relative lack of flexibility somewhat limits their usefulness. Although there is considerable controversy on the matter from experience gained it would seem that small lead shielded facilities come into their own where regular and well defined sets of operations have to be performed and therefore, fixed equipment can be installed for long periods of work. A good example of this is the balance box (see Fig. 4, *Nuclear Power*, May). For work of a rather undefined nature it is considered that the concrete cells using manipulators will give the flexibility of operation which is required. However, as pointed out, there has been a move towards an open area approach in the lead shielded facilities and this has resulted in a greater flexibility in operation.

From a general point of view the most outstanding developments that have taken place in remote handling connected with this work are three in number. Firstly, the development of techniques for working under α β γ conditions; this has resulted not only in the ability to examine irradiated materials but has given a very good measure of contamination control. Secondly, the use of non-professional labour has made an enormous difference to the amount of work that can be tackled. Thirdly, the introduction of the new concrete cells designed specifically to deal with α β γ activity without the use of either a frog suit or approach area is an important step forward. Experience will show whether this method of working is efficient.

STANDARDS OF WORKMANSHIP

As pointed out in earlier articles it is of outstanding importance that the standard of workmanship should be maintained at a very high level. This applies not only to rig manufacture but also to rig commissioning and to post-irradiation examination.

Although only briefly discussed previously the very careful and detailed pre-irradiation testing has become an important feature of the fissile irradiations. Equipment and techniques have been improved and it is interesting to reflect that if mass spectrometer leak testing detects a faulty weld which could cause a failure of one sodium filled capsule in the reactor, the saving achieved both with regard to the cost of the rig and the value of the scientific information obtained outweighs the cost of the mass spectrometer equipment many times. The maintenance of these extremely high standards cannot be over emphasized.

GENERAL CONCLUSIONS

In conclusion therefore the following main points can be made. It has taken several years to reach a state where experiments can be mounted with a high probability of success. This has resulted from an extremely close collaboration between the engineering, design and manufacturing team and the experimental staff responsible for the scientific experiments. The techniques that have been worked have seen extensive use in the reactors DIDO and PLUTO and their use is being extended to other material testing reactors. It is realized that improvements are always possible but new development should be aimed at these aspects where there is a very substantial advantage to be gained such as in the field of very high temperature testing for advanced reactors. It is considered that the state has been reached where the techniques are sound and although during the whole period of their development results have been obtained, it is now most important to utilize them to the full in order to obtain a closer understanding of irradiation damage in fissile materials.

Acknowledgments

The techniques that have been discussed in these articles have of course been the work of a very large number of people: it would be impossible to mention them all but they include members of the Design Offices, the Instrumentation Section, the Remote Handling Group and Reactor Operations. In particular the author would like to acknowledge the help of Messrs Ashburn, Chumbley, Causer, Dunbar and Rappe of the Engineering Division and Messrs Braunton, Venables and other members of his own group who have helped in both the development work and the preparation of the articles.

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Isotopes in the USSR

some new applications

THERE ARE two principal organizations primarily concerned with the Soviet isotope programme. The Administration of Production and Utilization of Radioactive Isotopes, Glavatom, provides the technical information, but the actual distribution is administered by the Department of Isotopes of the State Union Trust 'Sayuzreaktiv' of the Ministry of Chemical Industry under regular commercial agreements with the purchaser. An isotopes bureau, similar in scope to the one in London run by the UKAEA, has been set up.

Since 1957, with partial decentralization, Soviet scientific research centres in or near the capitals of certain republics have aimed at self-sufficiency in isotope production A stage has now been reached where a percentage of USSR production can be released as exports. In 1957, most of the 3000 shipments exported went primarily to the 'bloc' countries. Since then, shipments have increased with greater quantities going to countries outside.

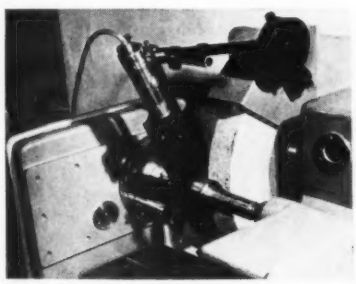
Examples of interesting new Soviet applications cover the fields of engineering, mining and food production. In the Moscow Likhachev Motor Works, the technologist is aided by equipment developed in the factory's own laboratories. One radioactive application is in the development of new cutting techniques and wear studies. The lip of the cutting tool under investigation is first irradiated in a reactor. During the cutting operations, controlled inside a glovebox, microparticles worn away from the lip adhere to the shavings. The machined parts and the radioactive particles are then analysed (Fig. 1). In the same works, mobile cobalt-60 installations are used for the quality inspection of metal welding and other components. The detection and photography of internal defects in steel parts up to 8 in is possible (Fig. 2).

In another engineering application, the grinding of shafts to very fine limits is done by automatic control. The caliper eliminates the possibility of human error and incorporates a radioactive detector ; as soon as the specified diameter is reached, a switch is actuated which stops the grinding machine (Fig. 3).

Quality inspection of welds (Fig. 2)

Some thought has also been given to the safety in mines. As a check against lung diseases and fire hazard due to coal dust, a portable back-scatter thickness gauge has been introduced by the Kharkov (Ukraine) Mine Surveying Instruments Factory. Using a thallium-204 source, the gauge keeps a constant check on the thickness of coal dust deposits.

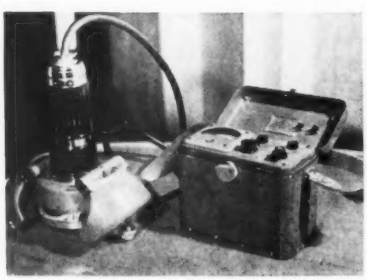
In the field of food production, improved productivity in poultry and increased egg laying capacity is being sought. At the Institute of Genetics of the USSR Academy of Science, radioactive preparations in doses which have no effect on vital processes, are introduced into the chicken's organism (Fig. 5).



Automatic control of shaft grinding (Fig. 3)

Increasing egg productivity (Fig. 5)

Investigating the wear of cutting tools (Fig. 1)



Checking coal dust deposits (Fig. 4)

PRODUCTION FIGURES

The estimated annual saving to Soviet industry through the application of radioisotopes is over £13 million. They are being used in several thousand industrial plants, in various fields of research, and for the improvement of agricultural techniques and production.

Types available

over 90 radioisotopes, 170 stable isotopes, over 360 labelled compounds, over 100 types of cobalt-60, caesium-137, strontium-90, and many others. (latest available information—1958).

Shipments

11,500	1954
26,000	1957

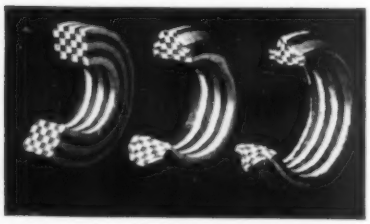
Quantities in total radium gram equivalent

2000	1955
over 90,000	1957

Rings for reactor pressure vessels

new forging process

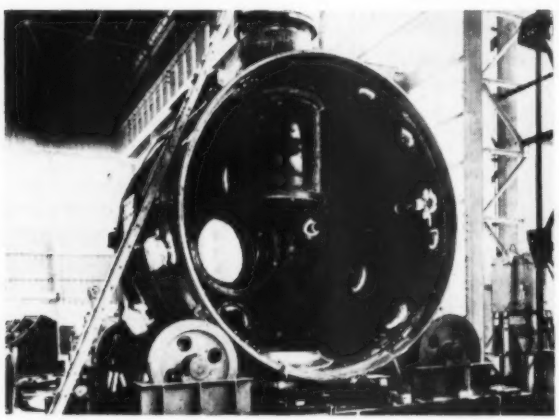
CUTTING HOLES IN the 4in steel plate forming the reactor pressure vessel weakens the shell considerably. This is particularly true for the CO_2 inlet and outlet ducts which are between 5ft and 7ft inside diameter. To replace the strength lost by cutting, a ring of very heavy section is welded in. The rings used at Bradwell, for instance, are roughly of a fluted triangular section, and the section is many times as deep and wide as the thickness of the shell itself.



Sections of model rings similar to those made for Latina show the three stages of forging—before, during and after shaping (Fig. 1)

It has not been possible so far to roll rings of such heavy section; to machine the special section from a ring of rectangular section is extravagant as more steel is wasted by cutting away than the amount left to make the ring. In collaboration with Whessoe, a method of forging almost exactly to shape has been developed at the Darlington Forge, reproducing the required form. Rings for the Latina nuclear power station, weighing 19 tons, have been forged in this way. Forging to shape has a further great advantage in that it produces a grain flow in the material which follows the shape of the ring, thus giving a much better forged structure. Model rings of laminated material were made during the development of this method and the sections show the grain flow effect during and after shaping (Fig. 1).

Reinforcing rings for the Dungeness heat exchangers after machining (Fig. 2)

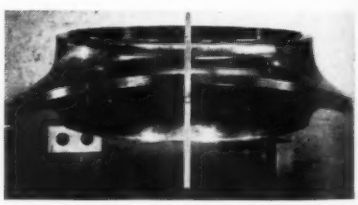


The AGR heat exchanger shell showing cambered rings fitted at the top and bottom of the vessel (Fig. 4)

Material sawn from this ring for Dungeness is used for mechanical tests (Fig. 5)

Reinforcing rings of a slightly different shape for the heat exchangers of the Dungeness nuclear power station have also been made by a variation of the new forging process (Fig. 2). Other rings have been made to reinforce openings in a cylindrical surface. The main flange is saddle-shaped or cambered, and a special process for producing this camber has been developed (Fig. 3). In the Windscale Advanced Gas-cooled Reactor cambered rings are used to reinforce openings in the cylindrical reactor shell, and for openings in the cylindrical heat exchangers (Fig. 4).

The absolute soundness of all these rings is most important; it is almost impossible to do any repair work, and quite impossible to inspect them once the reactor is working. All the rings, therefore, are ultrasonically tested to ensure freedom from internal defects. A special steel has been developed for making these forgings which is of weldable quality and meets the stringent notch-ductility and mechanical requirements. Material sawn from the forged rings is used for mechanical tests to ensure that the specified requirements are met (Fig. 5).



Darlington have produced this cambered flange for cylindrical surfaces (Fig. 3)

★ 280

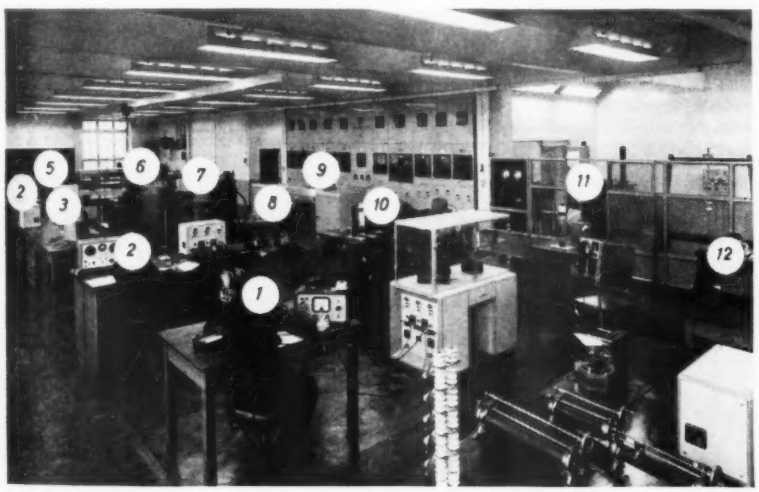
Electrical research laboratories

control gear development

ALLEN WEST'S NEW Proving Station and Research Laboratories, opened last year at East Moulsecoomb, near Brighton, are equipped to undertake under the most rigorous and precise conditions, the investigation of the construction and performance of electrical motor control gear throughout its development—from the first experimental model right through to full scale production. Gear to be tested ranges from the smallest push-button control switch to oil-break switchgear weighing several thousand lb. As an example of the work associated with nuclear power developments, tests have been carried out on contactor and switch fuse equipment for the Trawsfynydd nuclear power station. Control gear for Bradwell's 'Goliath' crane was also investigated.

Power sources from an adjoining motor generator room are fed to 25 service points within the laboratory; each has its own facilities for the control of voltage, current and frequency. The tests made involve the observation, measurement and recording of: temperature rise under full load and overload conditions; operating times and velocity of moving parts; magnetic performance; and analysis behaviour under various conditions. Typical of the instruments used are thermocouples, electronic time interval meters, flux meters, impulse generators and ultrasonic flaw detectors. Data on contact operation, electrical changes and other transient conditions is provided by either the Duddell electromagnetic oscillograph, or a cathode ray type of oscillograph.

For high voltage insulation testing up to 120,000V, a special area provides an inverted Schering bridge to deal with loss factor measurements, an electronic peak voltmeter, and an adjustable sphere gap. An anechoic chamber is used for investigations on noise and to detect high voltage discharge, aurally and visually.



In the development section of the Allen West laboratories a variety of work is in progress

1 Measuring close and release times of d.c. contactors with the aid of an electronic time-interval meter

2 Determination of the working voltage range of operating coils on some prototype d.c. contactors

3 Checking a coil for short-circuited turns by noting the degree of unbalance introduced on a sensitively balanced inductance bridge when the suspected coil is brought into close proximity to reference coil

4 Obtaining tripping-time/ampere-turn characteristics of overcurrent relays employing silicone oil as the delay medium

5 Stability measurements on an experimental timing relay

6 Routine battery charging

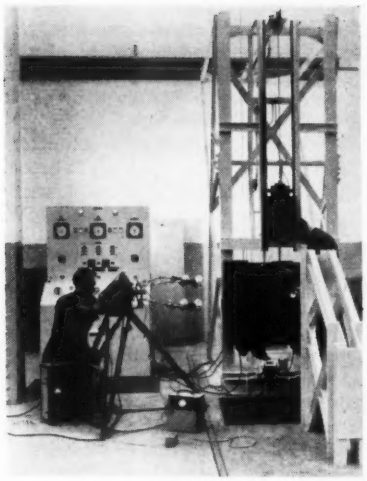
7 Investigation into contact kinematics to minimize bounce or chatter on a prototype d.c. contactor

8 and 9 Selecting and routing an electrical supply at the central distribution board

10 Checking operating coils for a new range of A.C. unit type contactors

11 Preparing for acoustic measurements on some a.c. magnets in the anechoic room

12 Evaluating the results of impulse voltage tests on some operating coils for which the small Marx generator (foreground) was used



Preparations are being made to record a shock test by high-speed cinematography

Endurance testing is a regular feature and the number of operations may run into many millions. Shock testing is another important aspect of the laboratory's work. Gear to be tested is mounted on a solidly-constructed test plate which receives the impact of a 400lb weight dropped from a height of up to 6ft. A lateral blow is delivered by swinging a similar weight through an arc of up to 90° and there is a further adjustment for an end blow of equal severity. Peak accelerations in excess of 2000*g* are possible.

Two devices are used for investigating the effects of vibration. They are a vibration table, on which can be produced a frequency range of 1-15c/s at a fixed amplitude of 0·1in, and a vibrating bar equipment where the frequency range can be extended from 15-120c/s. Observation of the behaviour of electrical components and assemblies under these conditions is made either by stroboscopes or by a high speed cine-camera which permits observation up to a speed of 8000 pictures per second.

★ 281

Data processing

new applications

Harwell's Mercury digital computer which has for some time, performed most of the establishment's major mathematical calculations, in addition to its use for the processing of nuclear data, has recently been provided with a punched card information input and output system, and with a line-a-time

printer. The new extensions, designed and built by Ferranti, increase the general power and flexibility of the installation. Identical modifications are to be made to the Mercury computer at the UKAEE, Winfrith.

Another Ferranti digital computer, the Argus, is to be used by Babcock and Wilcox for the control of start-up and shut-down of a 2000MW steam raising unit at the new West Thurrock CEGB power station. Start-up operations take about six hours and involve some 800 different controls. With differences in operating skill and experience, some 10% of start-up time can be accounted for. Argus will be programmed, therefore, to achieve more efficient procedures, in addition to providing records of the many variables that will form the basis of further calculations leading to additional efficiency.

The programme store holds 4096 instructions and the working store 1024 words. The input will accept up to 171 analogue signals from 97 transmitters and 32 three-term controllers. In addition, digital signals from 675 on/off devices can be accepted as well as readings from 150 thermocouples. The output provides digital drives to about 150 contactors.

There are two printers: an operations unit that gives details on computer operation and plant behaviour; the other prints boiler pressures and temperatures, metal temperatures, etc. as well as figures concerning plant efficiency and performance. The computer will also be used to monitor all essential alarm points and operating equipment.

★ 282

Trace reader

high speed analysis

Primarily designed for the study of pressure surges in aircraft hydrant fuelling systems, a new electronic trace reader has been developed by Shell that speeds up the analysis of continuous strip trace lines.

The record trace rests on a table moveable by means of two lead screws along x and y axes (e.g. time and pressure) in the horizontal object plane of a projection lens. A small region of the chart around the lens axis is illuminated and back projected at fixed magnification ($\times 4$) upon a conveniently placed viewing screen. This screen is ruled with two fixed intersecting diameters parallel to the table motions.

By moving the table so that the image of any point on the trace line coincides with the intersection of the viewer lines, each co-ordinate of that point is converted to a voltage between the sliders of a pair of multi-turn potentiometers connected in parallel. One is geared to the respective lead screw and the other is manually adjustable. The latter permits any point to be made the origin of co-ordinates by reducing the corresponding voltage to zero. Without disturbing the origin, the co-ordinate scales may be fitted independently to any linear chart calibration (usually to numerical correspondence) by manually adjusting the voltage across the appropriate pair of potentiometers.

The x or y co-ordinate voltage, selected by a switch, is displayed on a 0-999 digital voltmeter with an accuracy corresponding to one or two thousandths of an inch on the record trace.

★ 283

Viewing a projected trace on the Shell trace reader. The value of the quantity recorded by the trace is automatically registered on the numerical counter at the top when the cross hairs coincide with a point on the projected trace line

IN BRIEF

BRITAIN'S SCIENTIFIC ACHIEVEMENTS. The main theme for the British Section of the International Labour Exhibition to be held in Turin, from May 6—October 31, is the past and present achievements of science. Nuclear energy and research is represented by a working display of the Windscale Advanced Gas-cooled Reactor.

★ 284

PIPELINE RADIOGRAPHY. Iridium-192 from the UKAEA has been used for checking the butt-welding on the new 60-mile long, 18in pipeline linking the B.P. tanker terminal at Milford Haven with the Llandarcy refinery. With the radioisotope placed at the opposite side of the pipe for the duration of the exposure, photographs of the weld—one-third at a time—are taken on strips of film sandwiched between two sheets of lead foil.

★ 285

OCEAN FLOOR MANIPULATOR. A basic General Mills manipulator is being adapted for service in corrosive sea water at pressures of between 8-9 tons/in^2. For use with the US Navy's bathyscaph 'Trieste', the mechanical arm will be modified by means of special oil-filled units designed to equalize the pressures on motors and other critical parts.

★ 286

CO-OPERATIVE RESEARCH. The first arrangement of its kind in England and Wales, a scheme has been announced for sharing scientific equipment between over 100 industrial companies in South-East England.

★ 287

MEASURING LENGTHS ACCURATELY. Developed and produced by Carl Zeiss in Western Germany, the National Physical Laboratory has purchased a £16,000 metre interference comparator which will measure length standards to an accuracy of 1 part in 10 millions or better. The instrument uses the wavelength of monochromatic light as the invariable standard of length, and the phenomenon of wave-interference as the means of measurement.

★ 288

RESEARCH REACTOR NO. 1. Proving trials for AEI's 'Merlin', granted Reactor Site Licence No. 1, are nearing completion. Nine research projects are planned which include the investigation of radiation damage to UO_2 and semiconductors, Cherenkov detectors, fission product detectors and actuation analysis.

★ 289

DIGITAL COMPUTING SERVICE. Based on a Pegasus general-purpose digital computer at Hollinwood, Ferranti has set up a Northern computing service for industrial scientific and commercial calculations. Clients may prepare their own programmes or hand over the complete job to the computing service staff.

★ 290

MARINE RADIATION MONITORS. Air particle monitors for installation on board nuclear powered vessels are to be manufactured by Tracerlab. Weighing 500lb and 20in wide x 20in deep x 28in high, these radiacmeters provide visual and audio signals when the radioactivity reaches abnormal levels within the vessel.

★ 291

COBALT THERAPY UNIT. With the installation at Glasgow's Royal Infirmary of a cobalt therapy unit costing over £11,000, Scotland has its first deep X-ray facility. The 'Orbitron' made by AEI is surrounded by 4½ft of concrete contained in a building 20ft high. The special viewing window provided takes the form of a shell filled with 40 gallons of zinc bromide.

★ 292

★ *For further information on any item, circle the appropriate number on the reply card facing page* 106.

BUSINESS NEWS

AEI EXPECTS DUNGENESS GAIN **Associated Electrical Industries** expects to make a 'modest' profit on the building of the 550 MW Dungeness nuclear power station. In his annual statement, Lord Chandos, AEI's chairman, said the merger with **The Nuclear Power Group** had enabled large savings to be made in technical staff and in costs; operations now appeared to be adjusted to the likely volume of orders. Risks involved in tendering for Dungeness were less than those involved in tendering for the first station—Berkeley—when new ground was broken, as the earlier problems could now be accurately assessed. Lord Chandos added: 'I cannot but express my disappointment that the engineering and scientific effort at Berkeley may be rewarded with a loss. On the other hand, if you regard the money which we may lose as a development expense and not as a contractural loss, large though it may be, it brings the whole subject into clearer perspective'.

EQUIPMENT SHARING PLANNED A scheme for sharing scientific equipment between industrial companies in south-east England, believed to be the first arrangement of its kind in the UK, has been announced by the **Federation of British Industries,** London and South Eastern Region. Under this arrangement, a large proportion of the 126 industrial firms represented in these regions have submitted two lists of items of equipment—one showing the equipment they are prepared to lend and the other, equipment they would like to borrow.

EXPANSION OF EDWARDS GROUP **Edwards High Vacuum Ltd** is to acquire the whole of the issued capital of **J. H. Holmes & Son Ltd,** precision engineers. The acquisition is with a view to expanding Holmes as the specialised high precision machine division of the Edwards' group of companies, covering aspects outside the present facilities of the group.

UK FIRM WINS GAUGE ORDER A nucleonic gauge for measuring hot-rolled aluminium strip has been sold by **Baldwin Industrial Controls** to the Swedish firm **AB Svenska Metallwerken** of Finspaang. It involves a 500 millicurie strontium 90 source and is reported to be one of the first of its kind to have been installed in Sweden. Meanwhile, Baldwin's are understood to be negotiating for the supply of measuring gear to a Finnish paper and pulp plant. The order is worth some £3000. The firm sold, last December, 12 gauges valued at £12,000 to the Dutch strawboard industry.

NUCLEAR FUEL IMPORT DUTY An application for removal of import duty on nuclear reactor cartridges, spent or irradiated, is being considered by the **Board of Trade.** A statement of the applicant's case has been made available to firms and organizations who wished to make representations on the matter and who applied to the Board of Trade before May 12.

- **Hayward Tyler & Co. Ltd** received a £50,000 **Simon Carves** contract for supplying low pressure and high pressure glandless circulating pumps (eight each) for the Japanese Tokai-Mura nuclear power station.
- A new **Fafnir Bearing Co., Ltd** factory is to be built on a 20 acre site at Hednesford, Staffs.
- **Glenhill (Office Furniture) Ltd** is supplying the canteen furniture for Sizewell nuclear power station.
- The **UKAEA** is to exhibit aspects of its work at the West German triennial Chemical Engineering Exhibition and Congress, Frankfurt, June 9-17.
- **Dewrance & Co. Ltd** has formed the **Dewrance Metals Division.** It is responsible for production and sales of quality castings and 'Endewrance' hardfacing and high temperature brazing alloys.

OVERSEAS

COBALT-60 IMPORTS The **Hannover Institute for Petroleum Research** has imported a 7000 curie high specific activity cobalt-60 source from the USA. It will be used to study radiation chemistry processes in petroleum refining and petrochemical manufacture. A second source of 5000 curies will be delivered by the US for research into radiation-induced reactions. Equipment to handle the sources has been supplied by the UK.

LARGEST CARBIDE CONTRACT An order for approximately two tons of 3.7% enriched uranium carbide — said to be the largest single order ever placed for uranium carbide—has been received by the **Spencer Chemical Company,** USA, from **Atomics International.** The material is reported to be destined for use as prototype fuel elements for the AI sodium graphite reactor being built at Hallam, Nebraska. The material to be supplied is a new crystalline form of uranium carbide suitable for production either by compaction or melting and casting into fuel elements.

E. GERMANY OFFERS ISOTOPES The **East German Office for Nuclear Research** is now offering a wide range of radioisotopes for sale. It also offers contained sources of radiation and complements its range by imports from the Soviet Union. Meanwhile, the application of radioisotopes to measuring strip steel at the cold rolling mill in Oranienburg, East Germany, is reported to have made it possible to operate the mill at full speed and dispense with manually operated micrometers.

MATERIALS TESTING CONTRACT **Mitsubishi Atomic Power Industries,** Tokyo, has signed a contract with **Westinghouse Electric International Company**, to conduct nuclear materials testing for the Japanese firm at the Westinghouse Testing Reactor, Waltz Mill, Pennsylvania. Under the contract, Westinghouse will perform irradiation tests of uranium dioxide fuel fabricated by a swaging process developed by Mitsubishi. The programme will be completed within six months.

- Four **American Standards Association** committees are assessing and tabulating information on electrical measuring instruments used in connexion with ionizing radiation. They will report at the meeting later this year of the International Electrotechnical Commission's Technical Committee '45'.
- The Universities of Frankfurt, Padua and Lavel (Canada) and the Japan Atomic Energy Research Institute have placed orders worth over $2 million with **High Voltage Engineering Corporation,** USA, for 5·5 million electron volt positive ion accelerators.
- **AMF Atomics (Canada) Ltd** has completed an order for a new type of uranium oxide fuel element for experimental work at **Atomic Energy of Canada's** Chalk River establishment. The elements will be used in the 100 watt ZED-2 research reactor.
- **Radio Corporation of America** is now manufacturing a complete range of gamma ray gauging systems for industrial applications.
- Some 1000 delegates attended the **Seventh Commonwealth Mining Congress** in Johannesburg where 90 papers on various mining topics were presented
- A new Pye electronics factory to be opened in Northern Italy will be operated by **Pye Electronic S.p.A.** with offices in Milan.

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

STEREO TELEVISION

closed-circuit conversion

A simple optical system that converts any closed-circuit television equipment to a three-dimensional picture in minutes is available from Stereotronics. Requiring no electronic changes in existing equipment, this system consists of three devices: a 'stereo-captor' fits on the front of the television camera lens; a transparent stereo-screen is placed in front of the receiver and the viewer wears stereo-glasses.

The first device provides the camera with two views of the scene, transmission to the receiver taking place normally. At the receiver, the combination of the stereo-screen and stereo-glasses channel one of the views to each eye and create a three-dimensional image. The system permits group viewing from any normal distance or angle and the stereo-picture can be photographically recorded for future study.

★ 208

DETECTING IMPURITIES

resistivity meter

Originally developed at the UKAEA, Dounreay, for the accurate and continuous monitoring of impurities in sodium and sodium-potassium liquid-metal coolant circuits, the Bruce Peebles resistivity meter can detect an impurity concentration to a few ppm. The operation of the equipment is based on small changes in the resistivity of the liquid metal resulting from the adsorption by the coolant of impurities such as oxygen. The resistivity meter performs two functions: it measures absolute resistivity, and it measures small changes in resistivity resulting from the presence of impurities in the liquid-metal cooling circuit. An indication of the success of 'clean-up' processes is also given.

The meter head is a low-loss transformer with a main energizing winding, for producing the flux, and two secondary windings — one of which takes the form of a toroidal pipe, the other is in the form of a multi-turn search coil. The control circuit is basically a bridge circuit which is independent of frequency but is polarity-sensitive. An increase or decrease in resistivity is indicated by a positive or negative reading on an external recorder. Changes resulting from temperature fluctuations are discounted in the final reading by means of two decade switches on the control unit.

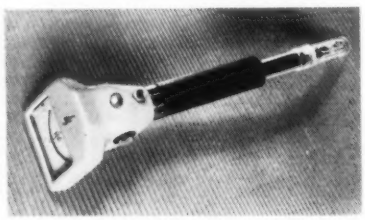
★ 209

The complete monitoring equipment for detecting liquid metals impurities comprises (left to right): a meter head, a compensator unit, a test meter, and the control unit

LIQUID CONTROL

portable pH meter

A new type of battery operated pH meter, which is simple to operate, has been introduced by H. G. Stevens.



This battery operated pH tester gives direct measurement when immersed in the test solution

Pressing a push button gives a direct reading pH value in the range 2-12, with an accuracy of ±0·1.

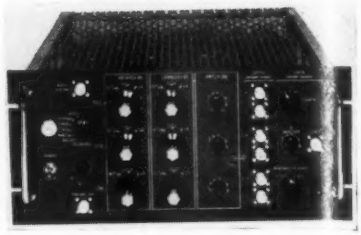
The immersion section, made of plexiglass, contains a single-bar special measuring assembly with a high resistance glass electrode. The meter head, built-in at the top, incorporates knobs for calibration, temperature control and needle adjustment. The total weight is just under 3½ lb and overall length 18½ in.

★ 210

MEASURING RESOLUTION

three-pulse generator

Designed particularly for measuring resolution times of coincidence circuits and scalers, and for simulating three-parameter programmes, the new Intertechnique generator, model GT10, delivers three rectangular pulses whose signs, amplitudes, widths and delays are independently variable. The repetition rate of the three-pulse pattern can be adjusted from 1 to 10,000/s. The low impedence output setting can be used



Each pulse in the Intertechnique three pulse generator can be adjusted in amplitude (positive and negative), length and phase

to investigate response of transistorized circuits.

A 'clock' pulse generator, consisting of a variable frequency multivibrator, sets the repetition rate of the three-pulse pattern. Internal synchronization covers the range up to 10,000 counts/s in four decades with an accurately defined setting at 4 kc (crystal controlled).

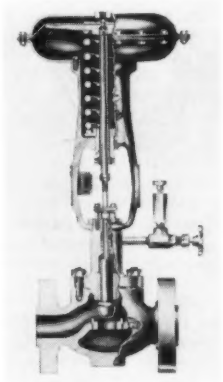
Each of the three generator channels includes a delay circuit, a pulse shaping circuit and an attenuator to adjust independently the output pulse delay, width and amplitude. In addition, a differential amplifier is provided on each channel to deliver, on separate outputs, a positive and a negative pulse, both available for simultaneous use.

★ 211

FLOW CONTROL

heavy-duty globe valve

Crosby have announced a completely new Masoneilan single seat heavy duty globe valve, the 20,000 series, which eliminates the orthodox bottom guiding in favour of extra heavy top guiding. This and other streamline design features give the valve a flow capacity almost equal to that of the equivalent line size double seat control valve. It will also withstand greater out of balance pressure across the seat



The new Crosby single seated diaphragm control valve combines the features of high capacity, high permissable pressure drop and a large range of interchangeable trims

and still give tight shut-off and stable throttling control.

Each size of valve is available with a wide range of interchangeable reduced area plugs and seats for temporary conditions, lower flows, and higher pressure drops, etc. The screwed type is available in the range ¼ in to 2 in with trim sizes ½ in up to 2 in; in the flanged range of sizes ¾ in to 10 in there are not less than four trim sizes for each line size valve.

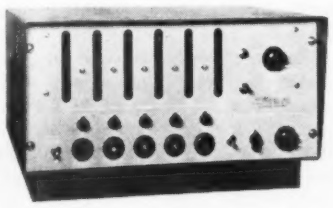
★ 212

COUNT RATE COMPUTER

nucleonic applications

The model QS-6 'Read-O-Matic' computer scaler, recently introduced by Atomation Inc, is a true events-per-unit-time computer designed for work involving medium and long time base intervals in nuclear, electronic, industrial and other applications in measurement and control.

Within the wide range of time base settings, the computed counting rate will



The 'Read-O-Matic' computer scaler can be used for manual or automatic sample counting, decay time studies, transient radiation analysis and other measurements

be displayed with the decimal point properly placed. The data are also available for read-out on an associated paper tape printer. Single or repeat-cycle counting is provided with adjustable delay times between cycles to enable visual or paper tape read-out.

Provision is made for ratio counting in which an unknown count rate may be read out as a per cent of a reference or standard count rate. A mode selector switch is used to select the quotient, ratio, preset time, preset count, manual count, or scan modes.

★ 213

OXYGEN ANALYSIS

portable instrument

Using the same magnetic susceptibility measuring cell as the Distillers' industrial unit, a portable oxygen analyser has now been developed by Servomex which can be regarded as an alternative to the Orsat apparatus for the determination of oxygen anywhere in the range 0-100% to an accuracy of ± 0·1%. Operation of the DCL 101 is simple and, as the device is linear, calibration at two points is sufficient to standardize over the whole scale. The zero is highly stable and a check of the span, using air as a test gas, is sufficient for most normal gases.

For routine oxygen determination, the analyser may be used with static samples or with a continuously flowing sample at rates up to 150ml/min. The sample must be filtered and cooled sufficiently to remove condensate but otherwise there are few restrictions. The measuring cell is not in any way affected by thermal conductivity or density variations. The instrument weighs 18 lb and is 13 in long, 8¼ in wide and 9½ in high.

★ 214

IN BRIEF

• **Welding electrode holder.** For handling heavier gauge electrodes at higher amperages, Interlas have introduced their new Terrier 600 special holder. The handle remains cold under extreme working conditions, using up to $^{5}/_{16}$ in dia. electrodes at up to 600amp.

★ 215

• **Profile polishing.** The new model CFT.40 automatic profile polishing machine of B. O. Morris is well suited to regular small run work. Its standard table of 40 in × 30 in can be extended by outrigger sections and a quick action jig traverses through its whole length against the polishing mop or abrasive band attachment.

★ 216

• **Water-proof switch.** Dowty's new micro-seal switch can operate in temperatures ranging from —75° to +70°C. Complete sealing is by glass/metal seals interposed between the switch tray and terminal block, together with a silicone-rubber 'O' ring and an associated nylon scraper ring in the plunger mechanism.

★ 217

• **Steel tubing.** Where pressures do not warrant the use of standard gauge tube, British Ermeto are now marketing a light gauge nominal bore steel tube with the minimum U.T.S. of 20 ton/in².

★ 218

• **Frequency measurement.** A new frequency and time measuring equipment, type TSA 3336, from Venner provides for measurement of frequency up to 1·1 Mc/s, inverse frequency (period), simple counting and time intervals in μs or larger units. The instrument can be reset remotely or locally by manual or automatic operation.

★ 219

• **Induction heater.** The model E9ZS induction heater of Delapena has been specially designed for zone refining. It has a power output of 9kW, an input of 20kVA, with an operating frequency of 4 to 5 Mc/s.

★ 220

• **Flow counters.** A new series of multi-purpose geiger-proportional flow counters, the FD-1 and the FD-2, are available from Tracerlab in 1 in and 2 in sizes. They will operate in the geiger region with standard G-1 gas or in the proportional region with argon-methane, pure methane or natural gas, without changing the centre wire.

★ 221

• **Nucleonic power supply.** Hamner's N-4050 high voltage power supply for nuclear applications gives a positive output of up to 5000V at 2mA, adequate for almost any type of proportional counter and sufficient for routine scintillation counting.

★ 222

• **Vacuum manometer.** Developed at the National Engineering Laboratory, N.G.N.'s new U-tube vacuum manometer reduces the error due to leakage of air into the closed limb, compared with other instruments. With the same volume of entrapped gas, the reduction of error is from 17mmHg to 0·33mmHg at 300mmHg.

★ 223

• **Space heat control.** Satchwell's new TM thermostat has been designed to give very accurate control in a wide variety of applications and for handling currents up to 20amp. Control is achieved by a new switch design and thermal element incorporating an accelerator heater.

★ 224

• **Closed-circuit television.** With a diameter of 3 in and measuring only 9 in from lens mount to backplate, EMI's new cylindrical closed-circuit television camera is suitable for use wherever space is severely restricted.

★ 225

• **Neutron shielding.** A new ICI development for fast neutron shielding—Boroplast—takes the form of plastic granules of boronated polythene or nylon surrounded by a hydrogenous material. Added to the plastic as a carbide or oxide, the boron concentration is between 1 to 10%.

★ 226

• **Scintillator paint.** An improved reflector paint for plastic phosphors and other scintillators has been developed by Nuclear Enterprises. It is a water-based emulsion containing a special grade of titanium oxide.

★ 227

• **Nuclear detectors.** A new US organization, the Oak Ridge Technical Enterprises Corporation, has announced its first products. These include high resolution silicon surface barrier detectors and stable low-noise charge sensitive amplifier systems for use with solid state detectors. For the detection of neutrons, ORTEC has available convertor foils coated with either Li-6 or B-10.

★ 228

★ *For further information on any item, circle the appropriate number on the reply card facing page 106*

W. A. C. MASKELL
GEC Communications

EARL LONG
General Dynamics

JOHN ROSS
Research head

A. A. SMALES
Harwell promotion

People

by John Radford

A RASH of news about travellers seems to have broken out in recent weeks. A three-man mission from the UKAEA has left for Sydney for discussions with the Australian Atomic Energy Commission on research co-operation. Members of the mission are **Dr H. Kronberger,** deputy managing director, reactor group; **Mr L. Grainger,** assistant director, AERE, Harwell and **Mr R. C. Orford,** commercial and overseas manager, reactor group. The plan is to spend some ten days in Sydney with much of the time spent with the Commission though visits to universities will be made. Also travelling is a group of leading Japanese nuclear scientists. They are visiting the USA under the auspices of the International Co-operation Administration to study the design, construction and operation of materials testing reactors. The ten-man team will visit AEC installations during their two month stay.

Of the individuals on tour recently, the most prominent has been the West German Atomics Minister, **Dr S. Balke.** He followed on the heels of **Sir Roger Makins** who spent some time in Spain recently, and visited Spanish installations during a seven day visit. His trip was in response to an invitation by the head of the Spanish Atomic Energy Commission who visited West Germany last September. Another prominent European on tour was **Mr Ludwig Rosenberg** chairman of the Economic and Social Committee of the European Economic Community and of Euratom. He spent three days in the Netherlands at the invitation of the Dutch Social and Economic Council acquainting himself with their working methods and relations with industry.

Following the appointment of **Dr R. Spence** as deputy director of the Atomic Energy Establishment, Harwell, **Dr W. Wild** has been promoted to head of the chemistry division. He is responsible for the scientific work of three branches: chemical processing and reactor chemistry; radiation chemistry and solid state chemistry, and radiochemistry. Dr Wild collaborated with Dr Spence in various gas kinetic and photochemical studies at Leeds University from 1931. In 1947, he joined the chemistry division at AERE as head of the radiation chemistry group, gaining a senior appointment in 1949. Later he became head of the radiation and solid state chemistry branch of the division.

W. WILD
Chemistry head

E. C. RIPPON
Parsons director

Another appointment as a director is that of **Mr E. C. Rippon** who has been co-opted to the board of C. A. Parsons & Co. Ltd. Formerly the firm's chief transformer engineer, Mr Rippon, has in the past year, been engaged in matters relating to the organization of design and production throughout the firm's works. For a number of years, he has represented British interests on international technical committees in the field of transformer engineering.

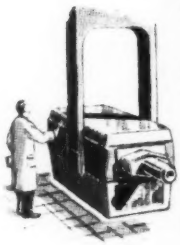
One of America's leading authorities on low-temperature physics, **Dr Earl A. Long,** recently joined the General Atomic Division of General Dynamics. He is assistant director of the John Jay Hopkins Laboratory for Pure and Applied Science. Dr Long was formerly professor of chemistry at the University of Chicago and director of the University's Institute for the Study of Metals. For several years he has been a consultant at General Atomic on reactor core materials research and development. Earlier, Dr Long was assistant director of the Los Alamos Scientific Laboratory and had served as a consultant to the Atomic Energy Commission.

The new managing director of the General Electric Company's Telecommunications Group at Coventry is **Mr W. A. C. Maskell,** general manager of the group since October 1959. During his 36 years service with the GEC, Mr Maskell has been chief engineer Radio Sales Service organisation (1935), deputy manager of the Radio Department (1946) and general manager of the Radio Works (1951).

Another appointment at Harwell is that of **Mr. A. A. Smales** who as head of the analytical chemistry branch, has been given the status of division head and will be directly responsible to the director AERE for the scientific work under his control. A London University graduate, Mr. Smales was sent to Oak Ridge during the war to assist in solving urgent analytical problems encountered in the electro-magnetic separation plant. He returned to his post with ICI at Billingham in 1945 and two years later joined AERE at Harwell.

Responsible for research and development for Metals & Controls Incorporated's Nuclear Products group, said to be America's largest manufacturer of fuel elements, is **Dr John Ross.** He has been named as manager of research and development and will also be heading the division's General Plate Products group, fabricators of clad metal products and the Spencer Products group, manufacturers of electrical and thermostatic controls. Dr Ross has a Ph.D in Physical Chemistry and worked at the Ames Laboratory of the Atomic Energy Commission.

Robert Carter-Pedler is the new sales manager of Photoelectronics (MOM) Ltd of Surrey.



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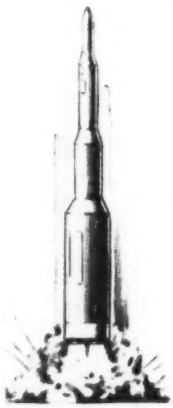

8-million-electron-volt linear accelerator under construction for atomic and process equipment division, A. O. Smith Corp., generates 6000 roentgens per minute at one meter — will radiograph 11 inches of steel in one minute (18 inches in less than an hour) at a standard nine-foot distance.

For the first time, radiographers can select — from High Voltage's complete line of supervoltage and high energy x-ray generators — the specific x-ray source of greatest effectiveness for high-speed, precise radiographic examination of thick sections, complex assemblies and special materials encountered in nuclear and defense industries.

Standard High Voltage equipments range from 1 and 2-Mev Van de Graaffs — providing constant-potential, point-source x-rays — to variable-energy 5-15 Mev linear accelerator x-ray generators with outputs of thousands of roentgens per minute at one meter.

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Burlington, Mass., U.S.A.

Affiliates: APPLIED RADIATION CORPORATION
HIGH VOLTAGE ENGINEERING (EUROPA) N.V.
HIGH VOLTAGE SERVICING CO., LTD., LONDON

Circle **No 49** on reply card for further details

STUDENTS' NOTEBOOK

GROUNDWORK—Processes

Reprocessing reactor fuel elements

In this issue Mr. Llewelyn and Mr Allardice describe the experience gained over 30 months in the operation of a chemical plant at Dounreay. Whilst the plant is used for the reprocessing of enriched fuel elements, many of the functions performed are typical and follow the steps described below.

For the economic operation of the nuclear power programme, irradiated fuel elements are processed not only to recover the valuable unused U-235, and the Pu-239 that has formed, but also to free them from fission products contamination. Various methods for the treatment of irradiated fuels have been tried and they follow in general the familiar types of ordinary chemical processing. Because of the very small concentrations of substances being handled in fuel element reprocessing, however, much smaller than those generally processed, normal procedures have to be modified.

Although several types of precipitation reactions have been used—the bismuth phosphate process in particular—and ion exchangers have had their application for laboratory scale separations, for separation on a production scale the methods currently used are those based on solvent extraction techniques. The oldest established processes use hexone (Hanford) or butex (Windscale) but a more economical solvent—tributyl phosphate—has now been introduced at Windscale; it is relatively more stable towards fairly strong nitric acid solutions.

Before the chemical separation processes can be started, the fuel elements are first left in water sufficiently to permit the decay of short lived fission products—particularly iodine and U-237—and then stripped of their metal cans by remote handling methods. They are then dissolved in strong nitric acid to produce a uranyl nitrate solution. Acid economy is effected by using the 'fumeless dissolving' process: $2U + 4HNO_3 + 3O_2 \rightarrow 2UO_2(NO_3)_2 + 2\,H_2O$. The efficiency and number of subsequent extraction stages depend upon the interaction and balance of the two phases—aqueous and organic. Relative densities are critical, and the greater the difference the more rapidly will the phases tend to separate.

In the initial cycle the uranyl nitrate solution, suitably diluted, is fed into the first of a series of extraction columns. After mixing the feed solution with the TBP and allowing the phases to separate, the uranium and plutonium transfer into an organic phase whilst the bulk of the fission products activity remains in the aqueous phase and is discharged to underground tanks. Before passing on to the second extractor, dissolved nitric acid in the organic phase is neutralized and the plutonium contained in it reduced to the trivalent state by ferrous sulphumate. Introduction of a dilute nitric acid stream backwashes the plutonium from the organic solvent, leaving the uranium behind.

The main uranium stream, now substantially free of plutonium and fission products, undergoes a further purification cycle to remove the last traces. Any plutonium left behind is efficiently removed by a ferrous sulphamate strip and a final pure uranyl nitrate solution is obtained by back-washing with very dilute acid. After evaporation, it is continuously denitrated at elevated temperature to yield a form suitable for handling.

Meanwhile, the trivalent plutonium in aqueous solution, containing an excess of ferrous sulphamate, is re-oxidized with sodium nitrite to the tetravalent form and then extracted into the organic phase, giving a further decontamination from fission-product activity. In the final treatment the plutonium is recovered in dilute acid and then concentrated by evaporation before going to the purification plant.

Acknowledgement

Acknowledgement to Messrs Newnes Ltd. for the use of the schematic diagram from Dawson and Long's 'Chemistry of nuclear power'.

NEWS

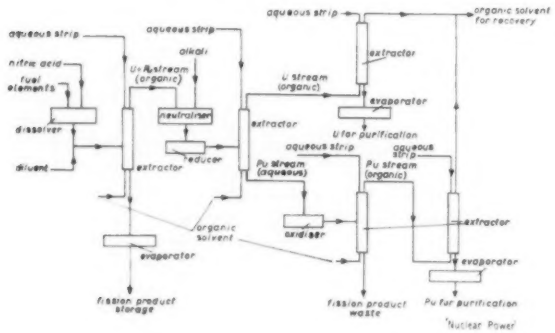
Progress in the USA Nearly £m6 in grants have been made since 1956 to US educational establishments by the AEC, mostly for reactor technology programmes. The future programme up to 1964 makes no allowance for further teaching reactors but intends to concentrate on equipment for colleges of arts and sciences and engineering colleges.

The Triga reactor to be installed at Columbia University, the first to operate in New York City, has been purchased from a National Science Foundation grant of $247,000. Meanwhile, an AEC grant of $34,700 to the Georgia Institute of Technology allows the purchase of fuel elements, flux converters and an antimony-beryllium start-up neutron source, for use in the heavy water reactor scheduled for operation by late 1962. 4·1kg U-235 and 8·7 tons of D_2O will be loaned without charge.

The Pennsylvania State University have received their 4MW pool-type reactor as a gift from Curtiss-Wright, the latter having previously operated it at their own Research and Development Centre. The gift also includes hot cells and other facilities.

In the accelerator field, a 2MeV High Voltage Van de Graaff has recently been installed at the University of Georgia where the research programme plans to cover studies on neutron polarization, neutron inelastic scattering, and (n,2n), (n,p), and (n,α). A three-stage tandem Van de Graaff 17·5MeV accelerator, and a separate 4MeV High Voltage unit, are to be installed at the new science-engineering centre at Texas University. Together with related instrumentation the total cost will be $M1·8.

• Suitable for laboratory groups of 30 students preparing their own samples, measuring radioactivity and interpreting the results, 23 experiments are detailed in a new 184 page manual 'Radioisotope experiments for the Chemistry Curriculum' from Nuclear-Chicago.



The first Windscale plant for the chemical treatment of irradiated fuels uses dibutyl carbitol (butex) as the solvent. After running for nine years a second separation plant is to go into operation which uses tributyl phosphate

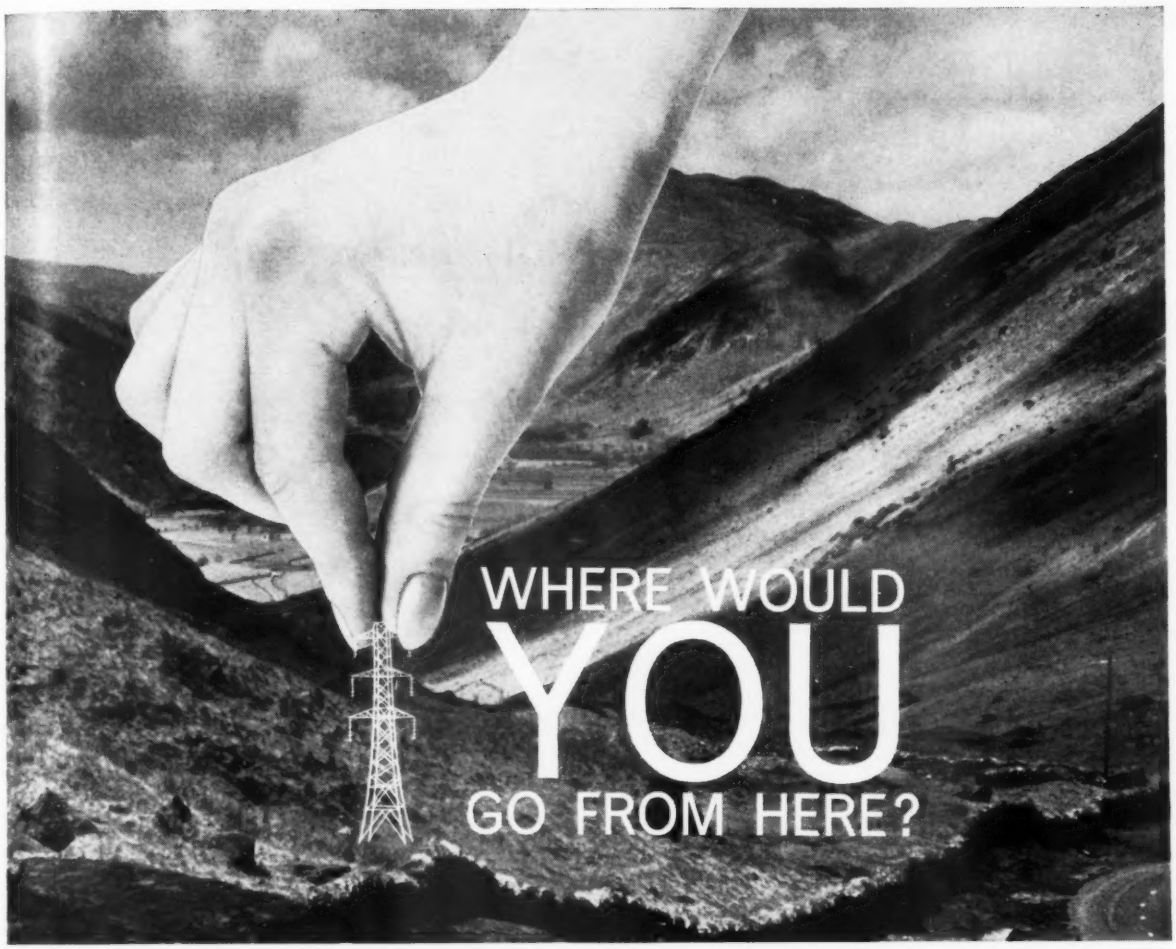
FILMS

• *The Dounreay fast reactor.* 4 reels, 37 minutes (UKAEA)
• *The Dounreay project.* 2 reels, 25 minutes. (UKAEA)
• *Chapelcross.* 2 reels, 20 minutes (in colour). (UKAEA) 3 reels, 31 minutes (in colour).
• *Operating a Calder Hall reactor—refuelling.* (UKAEA)
• *Operating a Calder Hall reactor—full power.* 2 reels, 20 minutes (in colour). (UKAEA)
• *Steel for nuclear power.* 2 reels, 18 minutes (in colour). (UKAEA)

All the above films are available in 35 mm or 16 mm on free loan from either the UKAEA (Risley or London) or the Central Film Library, COI, London, W.3

UK COURSES

Imperial College, London Summer School in Health Physics (Radiation Protection). July 3 - 14. Fee £26 5s
Borough Polytechnic, London Course on the Design, Use and Maintenance of Electronic Instruments in Nuclear Physics. June 26 - July 7. Fee: £5



Suppose for a moment that you are a wayleave officer working for the Central Electricity Generating Board. Your job is to plot a line bringing new power to an expanding town in the valley over the hill. Where do you go from here? The easiest and cheapest way would be up and across the crest of the hill. But the people in the valley (and the people visiting the valley) will take rather a poor view of that. By-pass the ridge and march down the valley itself? That would involve a three-mile detour, extra expense, and some unsightly angle towers. Bury the cables underground? An attractive idea but an impossibly expensive one, which could raise installation costs 17 times—with inevitable repercussions on the cost of electricity. There is no easy solution. But one must and will be found . . . one that fulfils the double duty which, by Act of Parliament, rests on the CEGB: to provide an efficient and economical electricity supply, while doing everything possible to preserve the natural amenities of the countryside. Please think of this next time you grumble at the towers: they are being carefully planned by men who value the countryside as much as you do.

■ **These advertisements are appearing in the farming and country magazines. The Central Electricity Generating Board thank electrical contractors for their co-operation in the past, and know that they will do all they can to preserve the amenities of the countryside.**

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Diary

19 MAY—4 JUNE
British Trade Fair and Exhibition, Moscow

23 MAY
Annual general meeting Society of Instrument Technology

29 MAY–2 JUNE
Conference on **property changes in reactor materials and radiation damage.** Bristol. Details, Central Electricity Generating Board, Berkeley Nuclear Laboratories, 7 St. Stephen's Avenue, Bristol, 1

30 MAY–2 JUNE
Radio and Electronic Components Show, Olympia, London

12-15 JUNE
British **Electrical Power Convention.** Eastbourne, Enquiries, Secretariat, BEPC, Wimsley Street, London, W1

12–17 JUNE
Electronic engineering conference on components and materials, Central Hall, London, SW1. Details, Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, WC2

15–24 JUNE
International construction equipment exhibition, Crystal Palace, London

19–22 JUNE
Summer meeting, Institution of Mechanical Engineers, Glasgow. Details, 1 Birdcage Walk, St. James's Park, London, SW1

19–22 JUNE
Laboratory apparatus and materials exhibition, Royal Horticultural Society New Hall, Westminster. Enquiries, UTP Exhibitions Ltd, 9 Gough Square, London, EC4

19–23 JUNE
International instrument show, 4 Tilney Street, London, W1 (B & K Laboratories Ltd)

21 JUNE—1 JULY
Sixth International **Plastics** exhibition and convention, Olympia, London

20-26 JUNE
Third congress, European Federation of Chemical Engineering, Olympia. Enquiries, Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

OVERSEAS

29 MAY–2 JUNE
IAEA symposium on the **effects of ionising radiation at a molecular level,** Brno, Czechoslovakia

29–31 MAY
44th annual meeting, Chemical Society of Canada, Ottawa. Details, Chemical Institute of Canada, 18 Rideau Street, Ottawa

1–3 JUNE
Second International **Powder Metallurgy** Conference, Eisenach, Germany. Details, Dr F. Thummler, Zentralinstitut fur Kernphysik, Rossendorf bei Dresden, Germany

1–15 JUNE
International medical-surgical meetings including second international meeting on **nuclear medicine,** Turin, Italy. Details, chairman, International Medical-Surgical Meetings, Palazzo Minerva Medica, Costa Bramante 83, Turin

8–4 JUNE
Annual meeting, American Nuclear Society, Pittsburgh

6–8 JUNE
Instrument-Automation conference, Toronto. Details, Executive Director, Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22

5–9 JUNE
IAEA symposium on the **effects of ionizing radiation on the nervous system,** Vienna

5–10 JUNE
Ninth International conference on **spectroscopy,** Lyons, France. Details, Groupement pour l'Advancement des Methodes Spectrographiques, 1 Rue Gaston-Boissier, Paris, 15e

9–11 JUNE
Congress on **radiology,** Budapest, Hungary. Details, Dr S. B. Szebok, chairman of the organizing committee, Ullot út 78, Budapest

9–17 JUNE
European convention on **chemical engineering,** Frankfurt. Details, Dr Bretschneider, Deutsche Gesellschaft für chem. Apparatewesen e. V., Dechema Haus, Frankfurt/Main, Rheingau-Allee 25

12–15 JUNE
International conference on **Physics of electronic and atomic collisions,** Boulder, Colorado. Details, B. Bederson, New York University, New York 53

12–16 JUNE
The technical writer and his relations to the expanding uses of communications in modern industry and government. Troy, New York. Details, Professor J. R. Gould, Rensselear Polytechnic Institute, Troy, New York

13–16 JUNE
IAEA symposium, **Whole body counting,** Vienna
International **gas chromatography** symposium, Michigan State University. Details, Meetings Manager, Instrument Society of America, 313 Sixth Avenue, Pittsburgh 22

13–17 JUNE
Annual meeting, Society of Nuclear Medicine, Pittsburgh

15–29 JUNE
Eighth international **nuclear congress** and exhibition on electronics and atomic energy, Rome. Enquiries, Fairs & Exhibitions Ltd, 2 Dunraven Street, London, W1

19–24 JUNE
International meeting on **heat transfer.** Paris, France. Details, Institut francais des Combustibles et de l'Energie, 7 rue la Perouse, Paris 16e, France

21–24 JUNE
Fourth international **Light Metals** congress, Leoben, Austria. Details, Montanistische, Hochschule, Leoben, Styria, Austria.

Industrial Literature

Remote handling. Manipulator - equipped vehicle systems for remote handling operations have a wide variety of applications, additional to nuclear use. A new booklet from General Mills discusses equipment and applications in situations involving explosive, radioactive, toxic and other hostile environments.

★ **250**

Protective coating. The properties of Ever-shield's liquid tile are described in Acalor's recent leaflet. A thermal setting resin, applied as a liquid, it bakes itself into a vitreous hard surface within 1-4 hours. It is resistant to radiation and can easily be decontaminated.

★ **251**

Steel research. The first issue of an English edition of 'Uddeholmaren', the journal of the Swedish firm Uddeholm, has been published. One article of interest covers research and development associated with the company's products.

★ **252**

Electrical measurements. The December number of 'Engelhard's Technical Bulletin' explains the working principles of the company's range of functional, portable instruments that measure d.c. and a.c. currents and voltages over extremely wide ranges of magnitude and frequency.

★ **253**

Nuclear aircraft propulsion. In a recent R.Ae.S. lecture, Professor Baxter presented ideas indicating possible trends in future nuclear aero engine design. A condensed version is published in the April issue of the 'de Havilland Gazette'.

★ **254**

Solid state technology. In the 'Westinghouse Engineer' for March, the value of solid-state device technologies is discussed, particularly the trend towards the integration of circuit functions into functional blocks.

★ **255**

Silicon nitride. The properties of 'Unamic' ceramics and their many potential uses in nuclear engineering and other fields are outlined in Union Carbide's 'Alloys and Metals Review'.

★ **256**

Transistor data. Information on some 3000 transistors from 90 manufacturers and distributors in the UK and overseas is included in an Avo manual published at 35s.

★ **257**

Variable-speed pumps. In the design of pumping installations, the trend is increasingly towards fully automatic operation. The March issue of the 'L.S.E. Engineering Bulletin' contains a detailed examination of the problems involved under the headings: choice of driving motor, automatic control principles, multi-motor systems, booster pumps and the recirculation flow control system.

★ **258**

Epicyclic gears. The use of epicyclic gears for high-speed, high-powered and high-torque applications has increased during the last ten years, according to an article in the March issue of the 'Allen Engineering Review'. A progress survey is made and mechanical design features are examined.

★ **259**

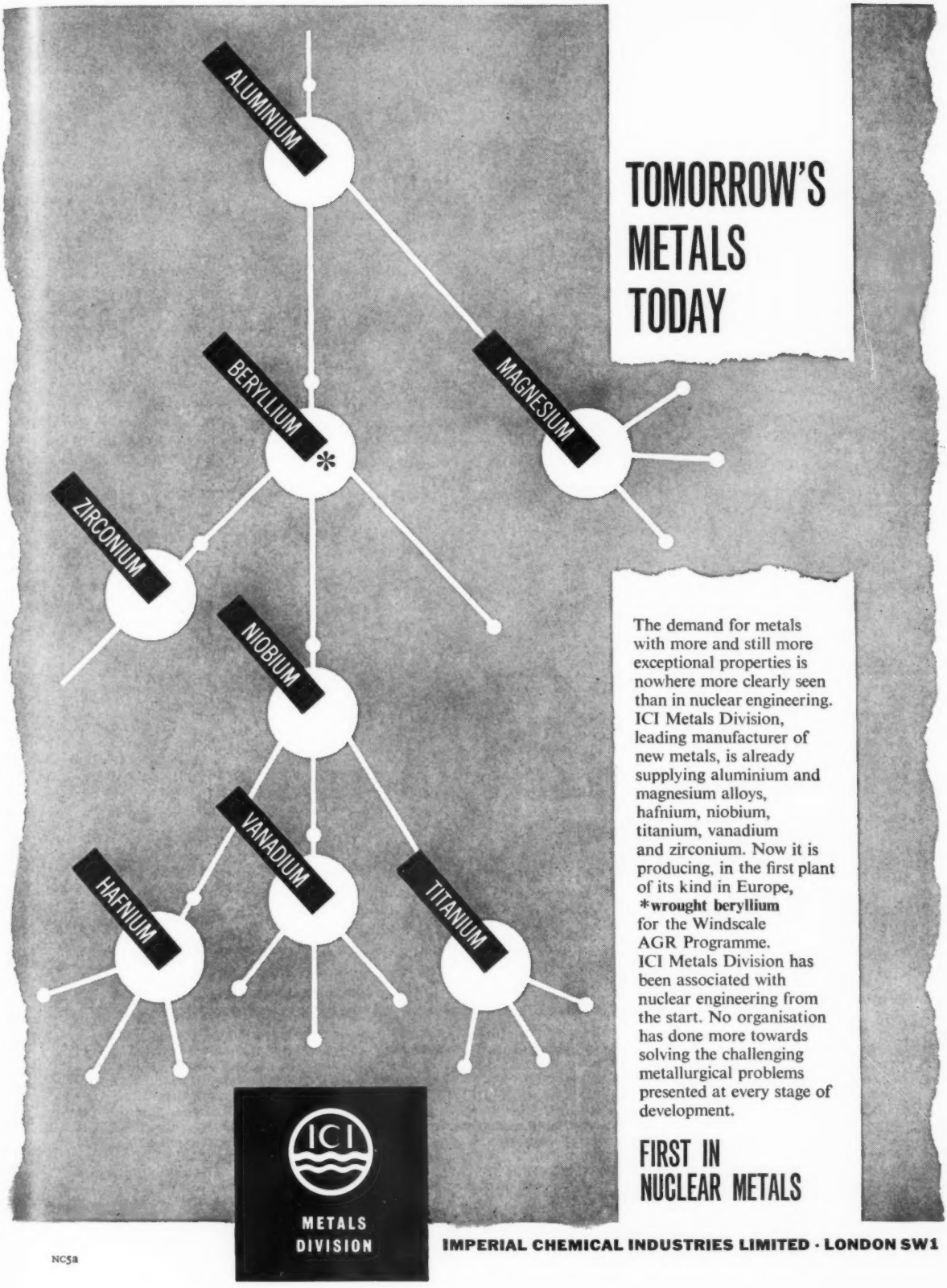
Induction heat treatment. The first article of a series on the Efco high frequency heat treatment service, which appears in the February number of the 'Efco Journal', covers generating plant, shop layout and work handling fixtures.

★ **260**

Creep machines. A range of creep and rupture testing machines, previously manufactured for special requirements, are described in a recent Nash and Thompson leaflet.

★ **261**

★ *For further information on any item, circle the appropriate number on the reply card facing page* 106



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Book Reviews

Nuclear power techniques

This textbook in German, 'Nuclear Energy Techniques' is designed as an introduction to the physics and engineering technology involved in the production of power from nuclear energy.

It is noteworthy for its wealth of clearly presented figures, graphs and statistics though it devotes more space to some reactor concepts than one would have thought warranted—the bismuth liquid metal fuel reactor, for instance, for which there is probably nothing like enough cheap bismuth in the world. Yet Calder Hall is given a scant two pages and the later magnox stations a bare mention. But 12 pages list the characteristics of homogeneous reactors, which may remain just a possibility.

The work contains a large amount of detail on ship propulsion units but the major approaches to controlled thermonuclear fusion are only briefly dealt with.

On the whole, the book should be a useful source of reference for the nuclear engineering student, provided he obtains information elsewhere on the well-tried gas-cooled reactor, of which more than 20 are being built—many more than any other type. **E.S.**

Kernenergie-Tecknik by H. Engel and K. O. Thielheim. Verlag Modern Industrie, Munich, 1960. 300 pp. Price DM36.

★ 262

More information on nuclear materials

This is an encyclopaedic volume of more than 1200 pages and does not bear much resemblance to the first edition of about seven years ago. The older edition was a compilation of limited usefulness because it represented only a small part of the knowledge available in secret files on the topics dealt with. Shortly after its issue the first Geneva Conference took place and, with it, a greatly relaxed attitude towards the "Classification" of data. This new edition reflects not only the relaxation of secrecy restrictions but also the vast increases in knowledge of nuclear materials over the past few years. This change is set in perspective when it is realised that in the first edition no significant data could be published on the irradiation behaviour of materials—a situation created partly by secrecy and partly by ignorance.

There are about 130 contributors and all, except one, are from the US. Their material is arranged in fifty-three separate articles under the headings: General, Fuel, Cladding and Structural, Control, Moderator, Coolant and Shielding Materials. The reviewer therefore looked forward with pleasure to a lengthy session with the book and, because it would be impossible in the time available to read all of the 1200 pages, a few topics were chosen for critical appraisal. The result of this sampling was disappointing and the conclusion could not be avoided that the good quality of binding and printing of the book obscured an essential shoddiness of writing and editing.

Let us look at the evidence for this. The reviewer first of all looked hopefully for something good on the irradiation behaviour of uranium. First to the index—there to find that 'Swelling' is absent (although it was later found to be the

READY SEPTEMBER 1961

AUTOMATIC AND REMOTE CONTROL

Proceedings of the First International Congress of the International Federation of Automatic Control (IFAC) MOSCOW, 1960

Editor: **J. F. Coales** *Co-editors:* **J. R. Ragazzini** *an* **A. T. Fuller**

★ **Volumes 1 and 2—Theory and Special Problems. Volume 3—Components. Volume 4—Industrial Application. Approximately 1,000 pages per volume. Approximate price £10 per volume.** ★

These volumes, which are expected to be published in September 1961, contain the papers read at the first International IFAC Conference (Moscow, 1960) together with the ensuing discussions. The Russian papers have been translated into English and are published in full. The papers reflect the most recent work in many countries and are divided into three principal sections. 1—Theory. 2—Components. 3—Applications.
The first section contains papers dealing with the present state of the theory of continuous and discrete systems, the theory of structures, stochastic and special mathematical problems of automatic control. In the second section the papers are devoted to the theory and practical work of designing electric, magnetic and pneumatic elements of control systems, programming and computing devices, controlling computers and systems of automatic control. The final section deals with design principles and the practical industrial application of automization in machine-building, metallurgical and chemical industries amongst others.

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★ 263

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Book Reviews

heading of at least two sections). Diligence, however, led one to a page or two on irradiation effects in uranium. Diligence was less rewarded when looking for some unequivocal statement about the behaviour of a single crystal of α-uranium when irradiated—an essential key to the whole story. It was perhaps interesting, though hardly essential, to find from this search that a single high temperature test costs $100,000! After some half dozen pages dealing with many physical and mechanical properties (1331–39) we find from the headings that we are to learn about radiation damage hypotheses, Implications of irradiation damage, and Fission product effects, in that order. Bewildered by this apparently topsyturvy ordering of subject matter it was not surprising to find that the headings continued with Dimensional Instability, Thermal Cycling and Mechanisms of Growth. Perhaps, Chinese fashion, this chapter was meant to be read backwards, but as it stands, it cannot conceivably be thought to be up to final year undergraduate standard. The, by now dejected, reviewer proceeded hoping to be enlightened about uranium alloys. Well, he was in a way, because it was here (p. 191) in a chapter on alloys (headed 'Swelling'—see above) that he found that *un*alloyed uranium changes density on irradiation due to fission gas. This was the sort of information looked for earlier (and surely appropriate to the previous chapter), but it was somewhat irritating to find that the supporting numerical data, supposed to have originated in the UK, was given no reference—the irritation here was caused by the serious doubt the reviewer had of the accuracy of the statement, and there was nowhere to turn for confirmation or refutation.

Pressing further on to find enlightenment about irradiation behaviour, we thought we would chase the story on uranium-molybdenum alloys. Here was material to be harvested—yes, we find that gamma stabilized uranium-molybdenum alloys undergo only minor swelling even at such a high temperature as 600°C. Let us now ask the question why. Alas, the reader will probably have to look beyond these 1200 pages for an attempted answer, because this reviewer could find no discussion of this question. Shortage of space can be no excuse because nearly two pages (180–181) are devoted to almost indigestible tables of mechanical properties of these alloys.

The difficulties of explaining irradiation behaviour may have dimmed the wit of authors and detracted from an accustomed lucidity of exposition which would be recovered on some more familiar topic. Turn then to magnesium, perhaps to discover features for gentle praise. However, more cause for raised eyebrows—Magnox can contain up to 0·4% Calcium (Table 24.1). This sent your reviewer post-haste to see how this stuff would weld. Certainly there is a section on welding (p. 599) from which we discover by implication that there are no major difficulties, no flux is required with the gas shielded arc and a few other trite niceties of detail are set out. Your reviewer was left wondering why there had been all the bother about Magnox compositions and why had UKAEA made so much fuss about welding. National pride had a final deflation on being told that 'One of the most *probable* (reviewer's italics) applications of magnesium in a reactor is based on its lack of solubility in uranium' (p. 601). True enough about the solubility but 'probable' indeed.

This handbook contains much data but it does not seem to have had the critical care and attention in its preparation which a book of this pretentiousness requires and which the user must be able to rely upon if he is to get value for money.

J. G. Ball

Reactor handbook, 2nd edition, 4 volumes. Vol. 1: Materials, edited by C. R. Tipton. Interscience, New York & London, 1960. 1200 pp. Price £13.

★ **264**

First treatment of pion physics

This volume is the first to be devoted to topics in the field of high energy nuclear physics as practised with particle accelerating machines, but the treatment is quite specific and limited to pion physics. Pions, or π-mesons as they were originally called, were first discovered in cosmic ray studies by Professor Powell and his colleagues in 1947, some years after their existence had been postulated on theoretical grounds by Yukawa. Most of the work since then, to study their properties and their role in nuclear forces, has been carried out with the help of cyclotrons and synchrotrons in laboratories in the US and in Europe, including the Dubna laboratory in Russia. It is the purpose of this monograph to review and discuss the experimental and theoretical work in this field, and Dr. Lock has done this admirably. Although the book is addressed mainly to experimental physicists and post-graduate students working in the field, it is hoped that final year honours undergraduates in physics might also be persuaded to read it, since it contains much that is pertinent to our 'modern physics' in the last decade.

To keep the size of the book within reasonable limits, the author has, in my opinion, rightly omitted the subjects of high energy electron scattering and strange particle physics. The book is written in a style that is easy for reading. It forms a comprehensive review of the subject and, at the end of each chapter, further reading is suggested in adequate bibliographies and references.

W. Galbraith

High Energy Nuclear Physics by W. O. Lock. Methuen, London, 1960, 190 pp. Price 18s.

★ 265

New Books

- *Progress in nuclear energy, series IV*—Technology, engineering and safety, volume 3 edited by C. M. Nicholls Pergamon, London 1960 448 pp Price £5 5s

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- *Eléments de physique nucléaire* by D. Blanc and G. Ambrosino Masson, Paris 1960 238 pp Price NF30

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- *Nuclear reactor containment buildings and pressure vessels* Royal College of Science and Technology, Glasgow—Symposium 1960 Butterworths, London 1960 572 pp Price £5

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- *Elementary introduction to nuclear reactor physics* by S. E. Liverhaut Wiley, London & New York 1960 447 pp Price 78s

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- *Selected papers on stress analysis* Delft Conference 1959 Chapman & Hall, London; Reinhold, New York 1961 114 pp Price 50s

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- *Directory of nuclear reactors* Vol 3- Research, test and experimental reactors, Suppl. to Vol. 2 IAEA, Vienna 1960 354 pp Price 24s.

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- *Dictionary of electronics* by Harley Carter Newnes, London 1960 377 pp Price 35s

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- *Soviet technology digest* new monthly journal Pergamon, London First issue December 1960 annual subscription £10

★ **273**

- *Introduction to modern physics* by C. H. Blanchard and others Pitman, London 1960 420 pp Price 37s 6d

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- *Kempe's Engineers Year-Book* 1961 Morgan, London 2 Volumes Price 87s 6d

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- *Russian for the scientist* by J. and L. B. Turkevich Van Nostrand, New York and London 1959 255 pp Price 25s

★ **276**

- *The fundamental atomic constants* by J. H. Sanders Oxford University Press 1961 88 pp Price 10s

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- *The chemical industry in Europe* 1959-1960 OEEC, Paris 1961 221 pp Price 17s 6d

★ **278**

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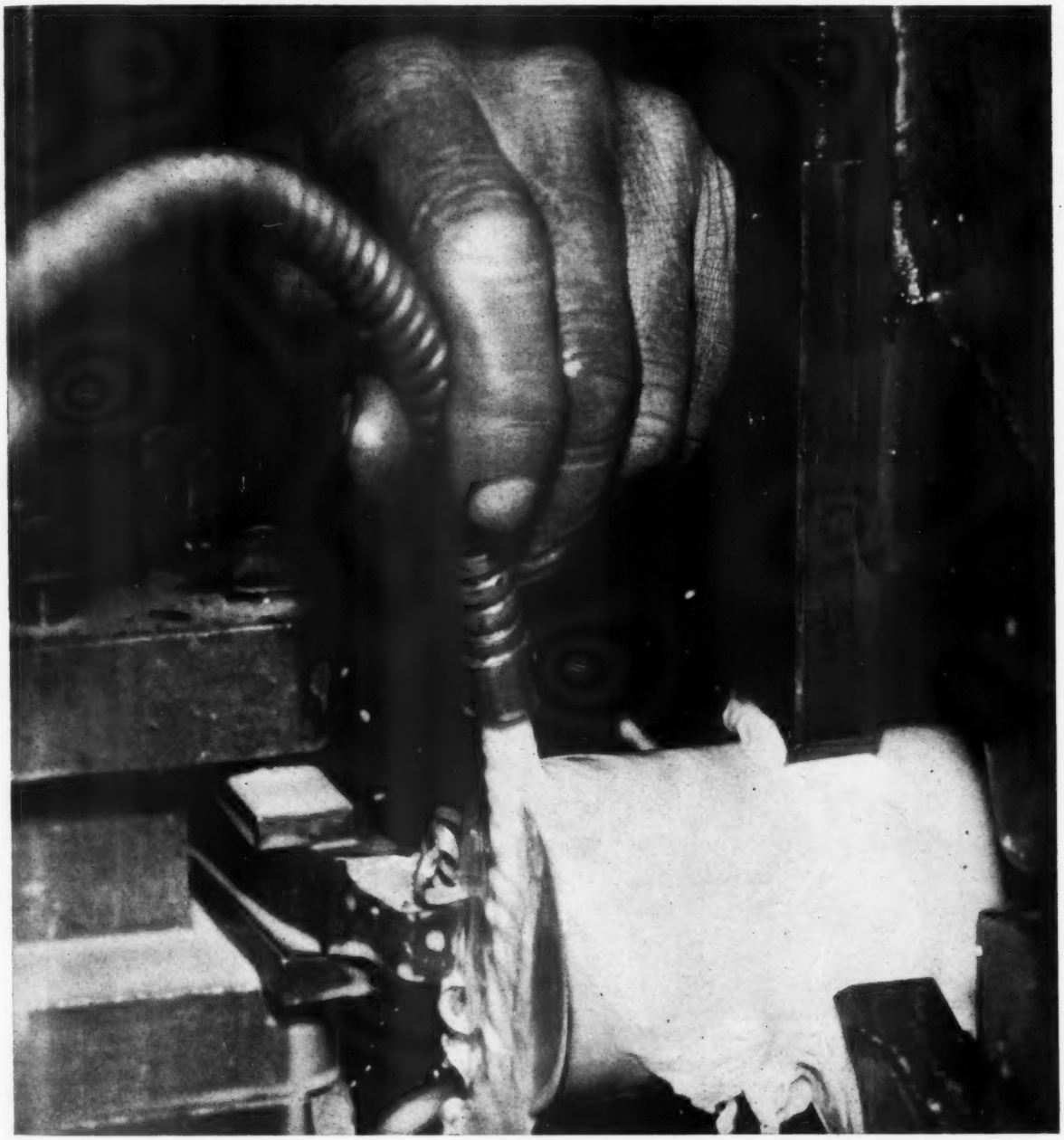

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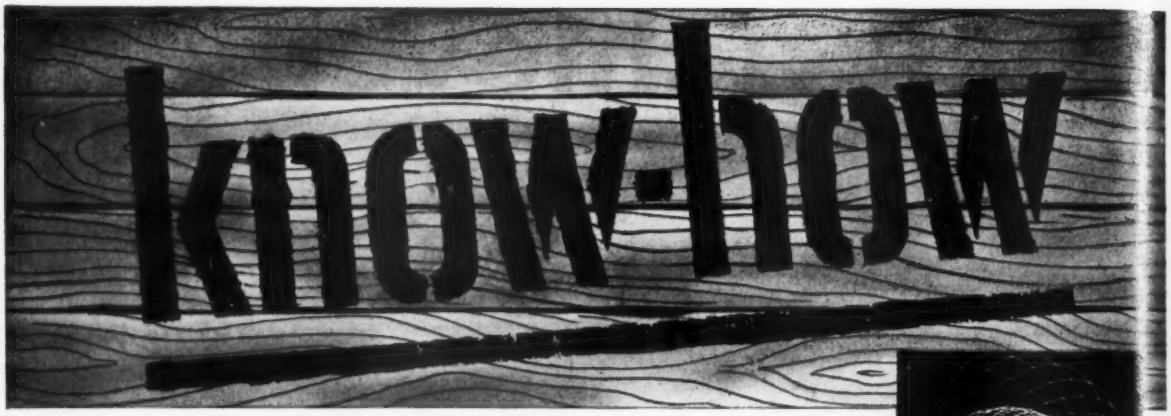

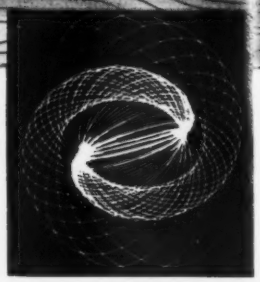

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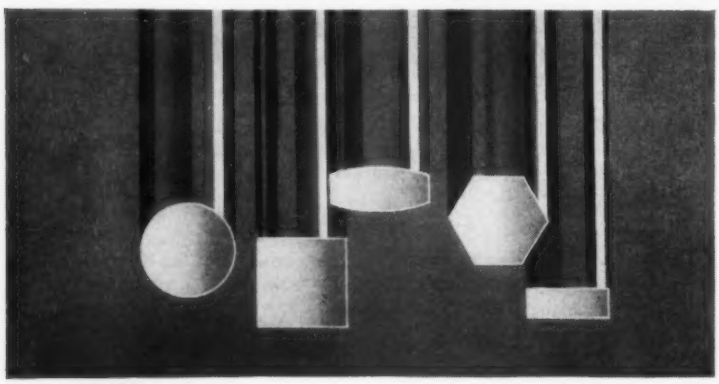

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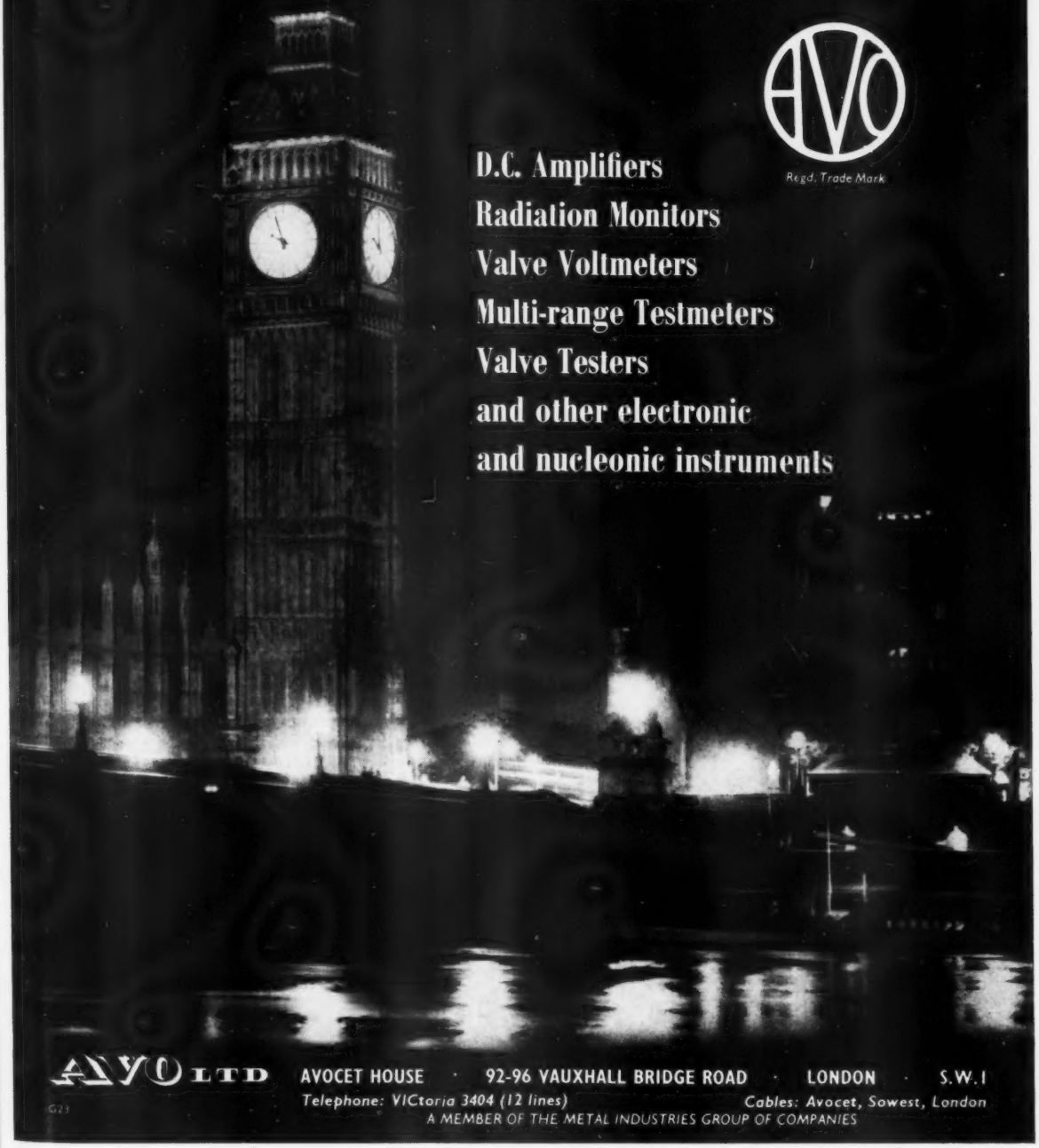

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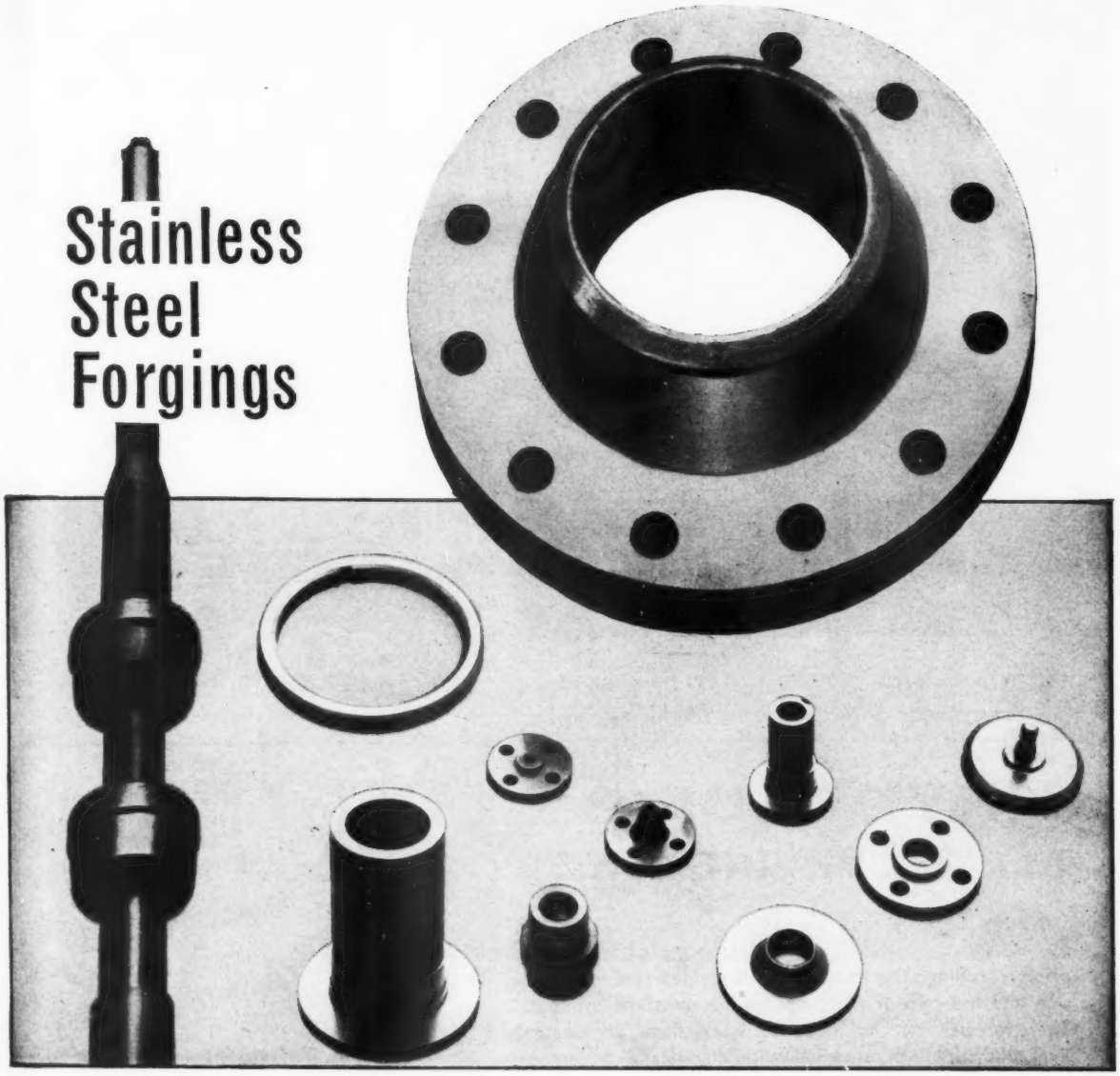

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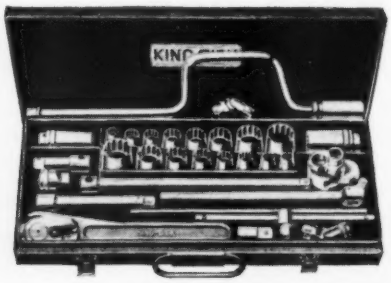

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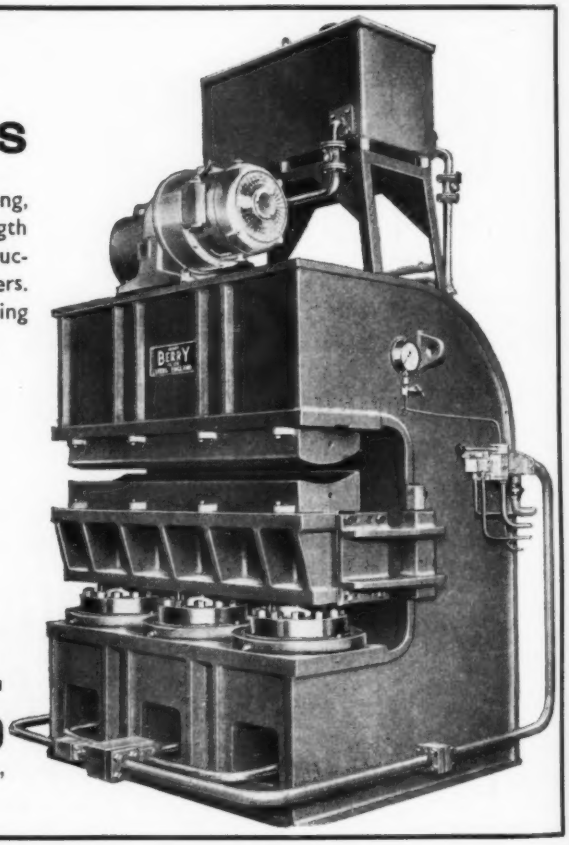

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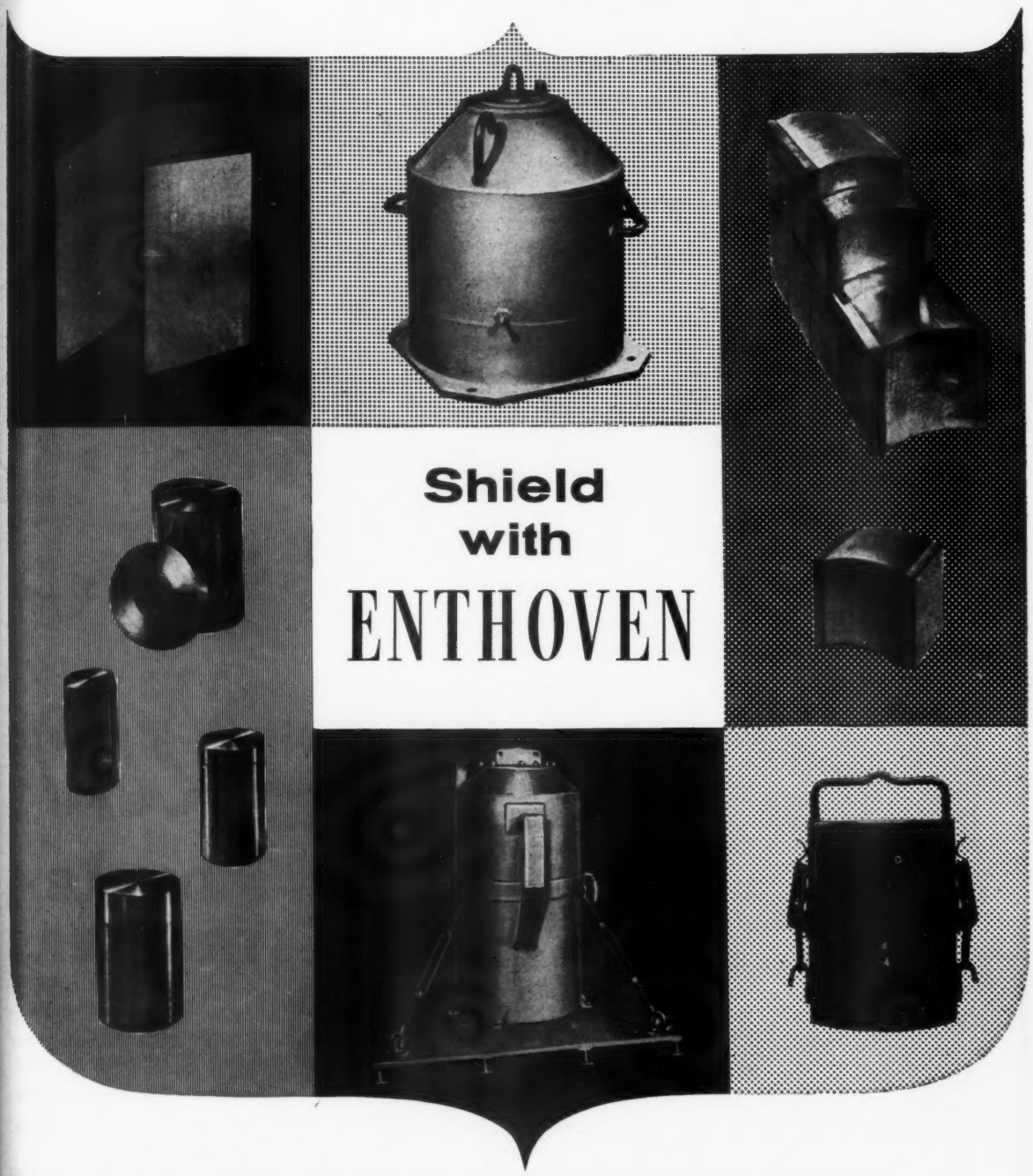

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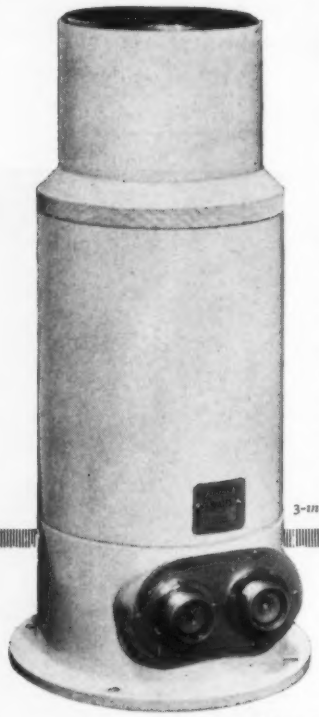

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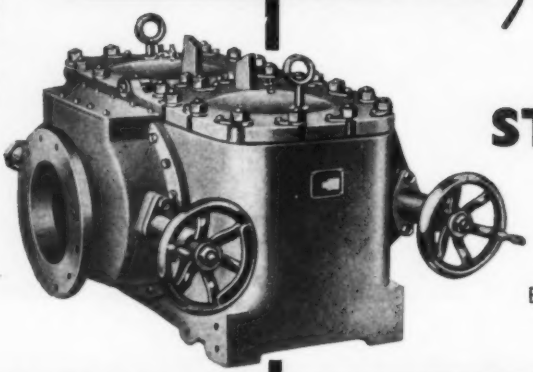

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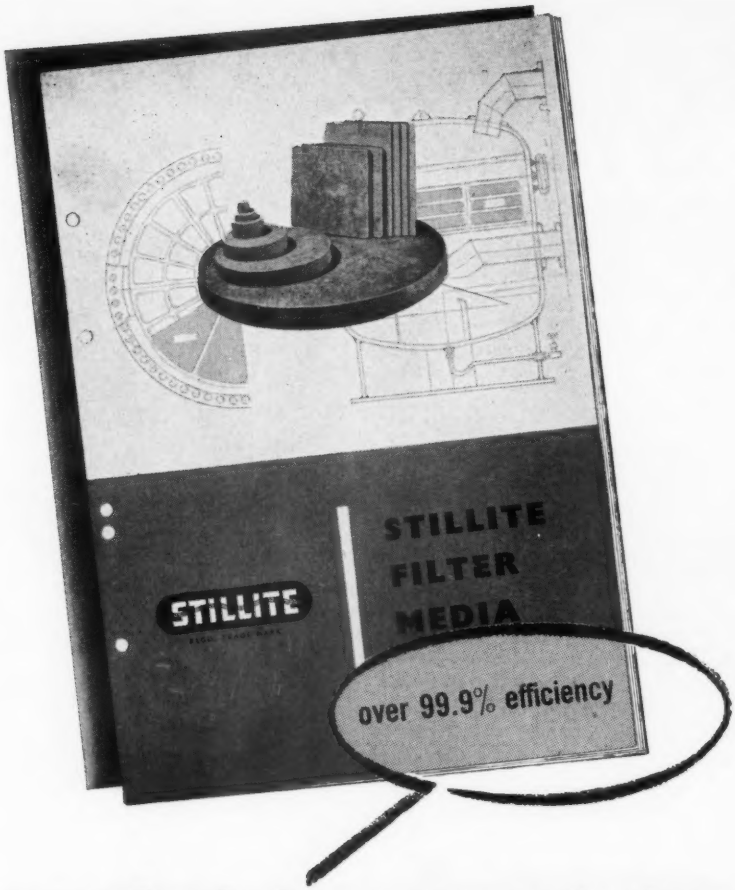

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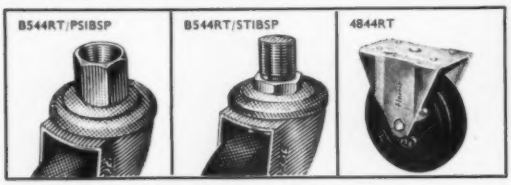

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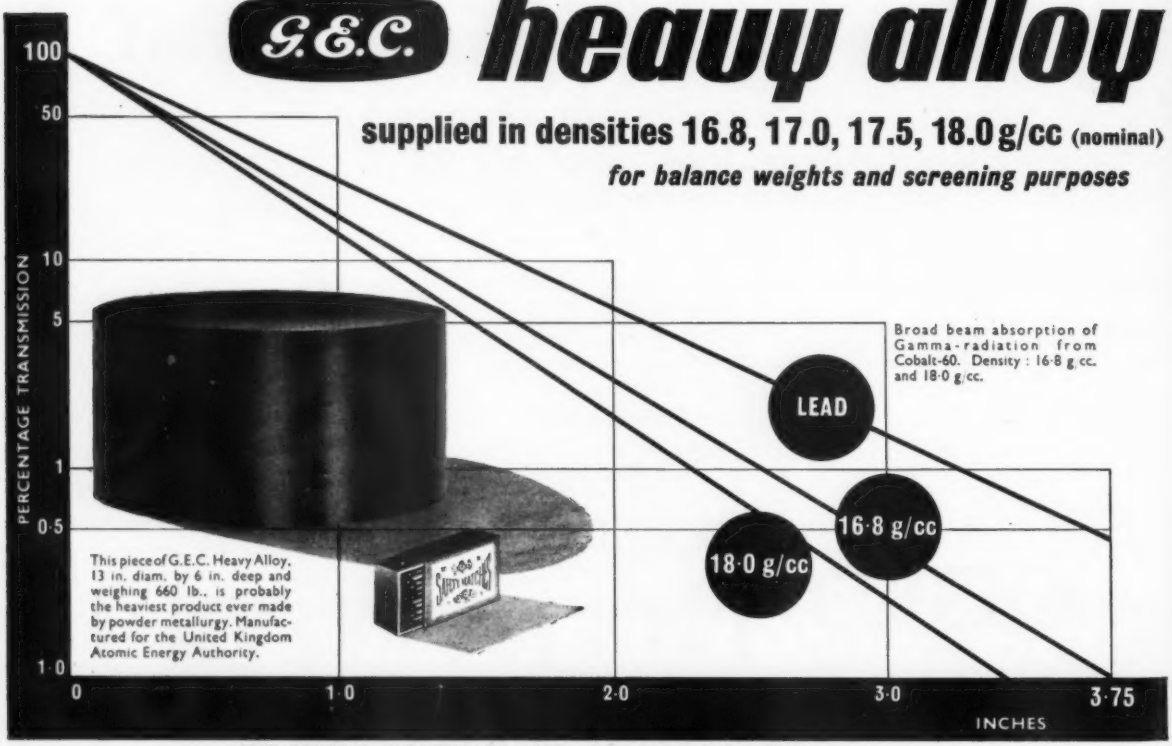

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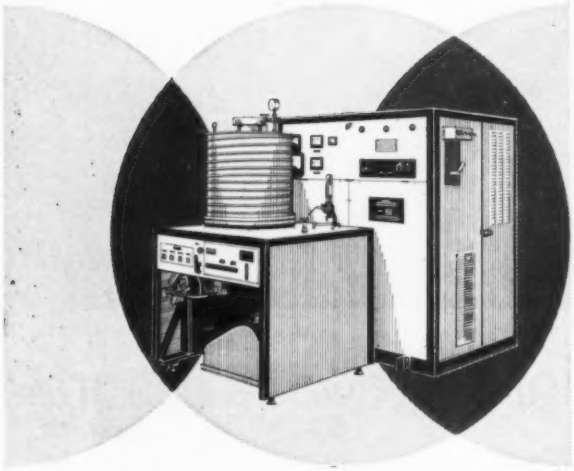

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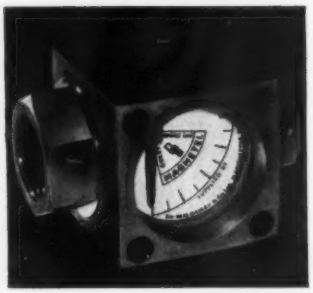

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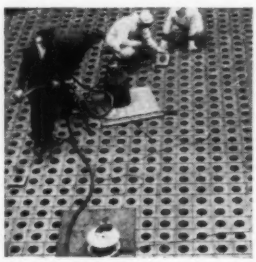

Simplex model removing dust within No. 1 reactor at Bradwell, on 25th June, 1960.
Photo by kind permission of The Nuclear Power Group, Bradwell and the Central Electricity Generating Board.

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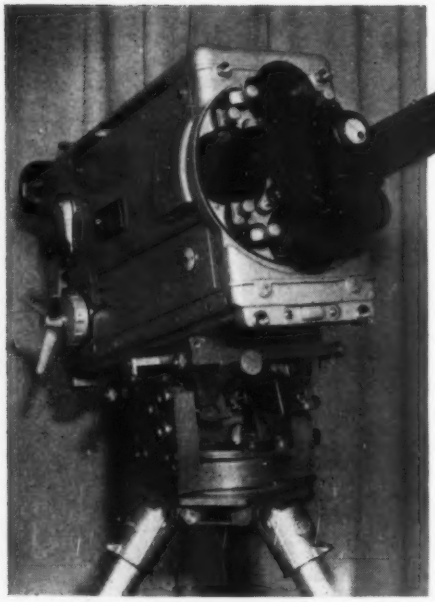

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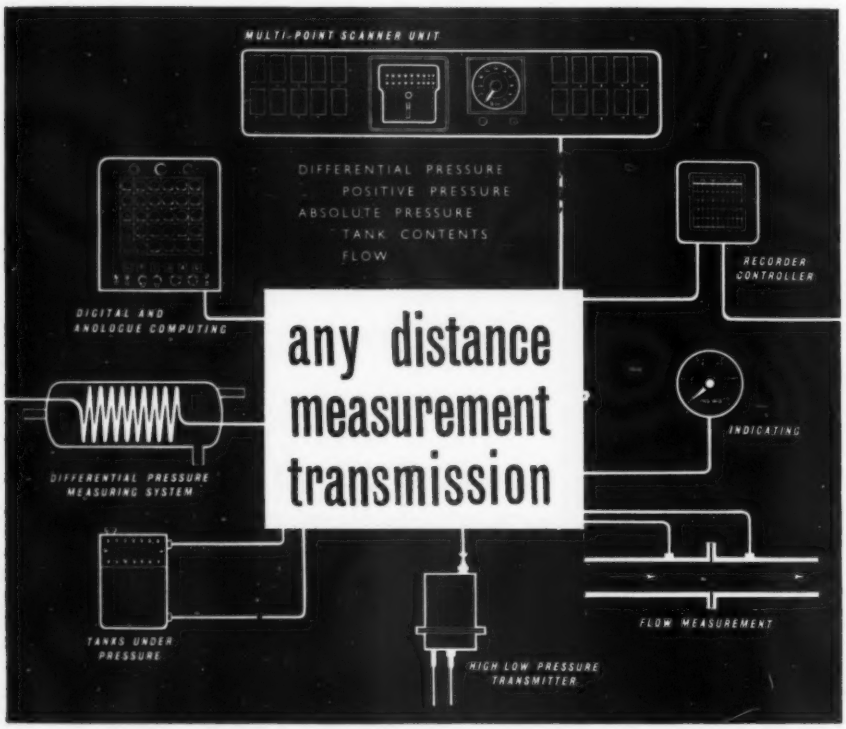

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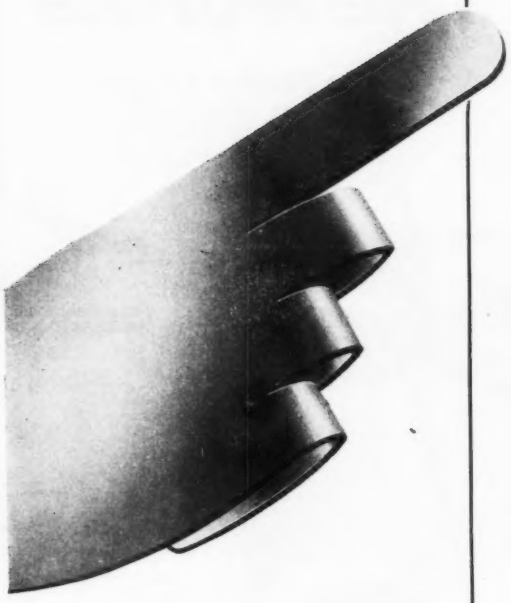

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Maximum Permeability	200 000	100 000	30 000	100 000	10 000	70 at 0 C 48 at 20 C
Saturation Ferric Induction (gauss)	8 000	8 000	16 000	16 000	12 000	3200 at 0 C
Remanence, Brem, from saturation (gauss)	5 000	4 700	10 000	11 000	3 500	2200 at 20 C
Coercivity, Hc. (oersteds)	0.01	0.04	0.15	0.04	0.30	
Hysteresis loss at B sat (erg/cc/cycle)	13	38	1 000	400	450	
Curie Point (C)	390	390	500-550	500-550	280	60

H.R.C. A rectangular hysteresis loop alloy for Magnetic amplifiers and saturable reactors. Saturation induction: 15 600 gauss Retentivity: 15 000 gauss Coercivity: 0.13 Oe Hysteresis loss — 650 ergs/cm³/cycle Bmax = 15000

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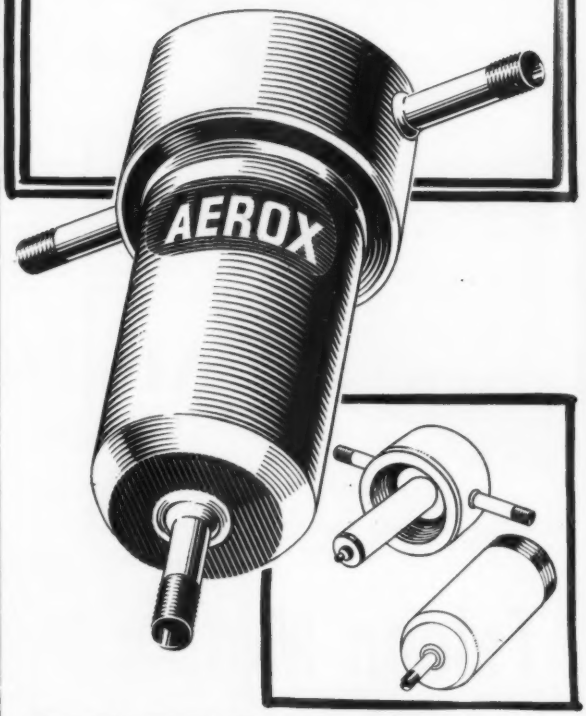

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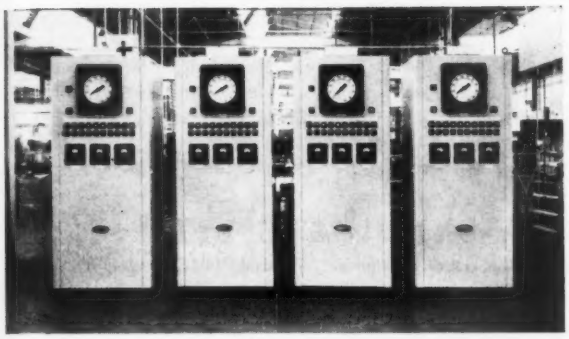
A healthy outlook for Berkeley



We acknowledge with thanks the courtesy of A.E.I.—John Thompson Nuclear Energy Company Ltd., (a Partner Company of the Nuclear Power Group) in granting us permission to publish this photograph.

Berkeley, one of Britain's first two commercial nuclear power stations, now nearing completion for the C.E.G.B., will have CO_2 in air monitors to give warning of CO_2 concentrations which might occur in the remote possibility of leaks from the cooling system. A large number of sampling points in the Blower House, B.C.D. Rooms and Fan Annexes will be checked in rotation and alarms will operate whenever the concentration of CO_2 reaches a set value. Typical check points include blower seals, blower lubricating pits and blower house control room.

The primary measuring equipment for these monitors has been supplied by Cambridge Instrument Company Ltd., to the specification of A.E.I. — John Thompson Nuclear Energy Company Ltd. Our illustration shows four of the cubicles, which carry some of the apparatus, lined up at the A.E.I. Instrumentation Division premises Harlow, Essex. Each of these cubicles is equipped with a Cambridge Electronic Indicator, designed to accept the ouputs of the analysing katharometers in turn. Because of the electronic indicator's high speed of operation, it is possible to monitor all ten sampling points (each cubicle) in less than 40 seconds.

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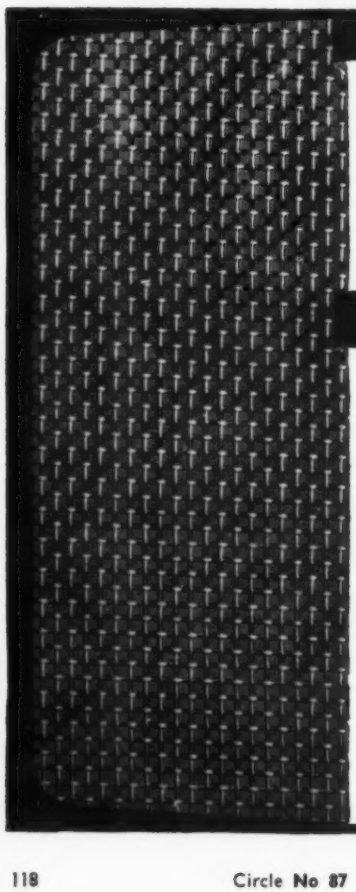

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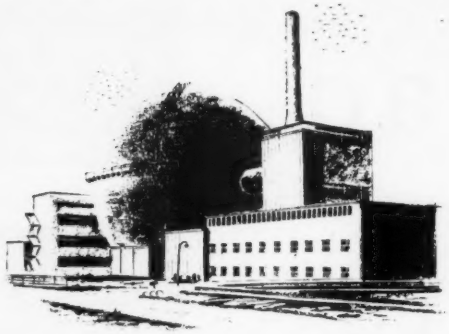

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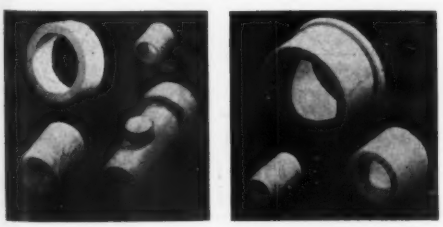

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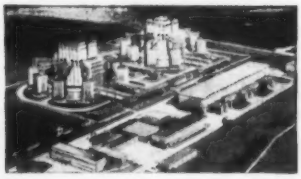

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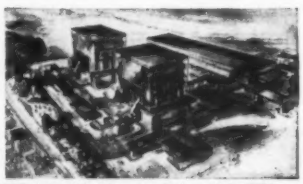

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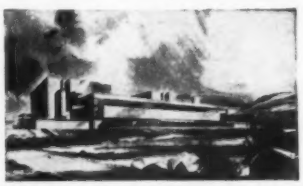

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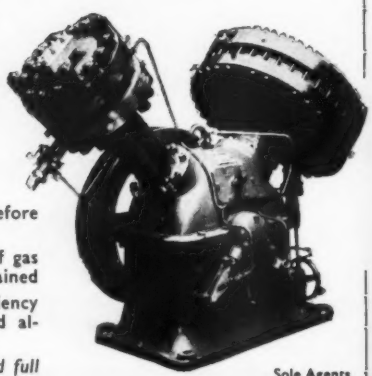

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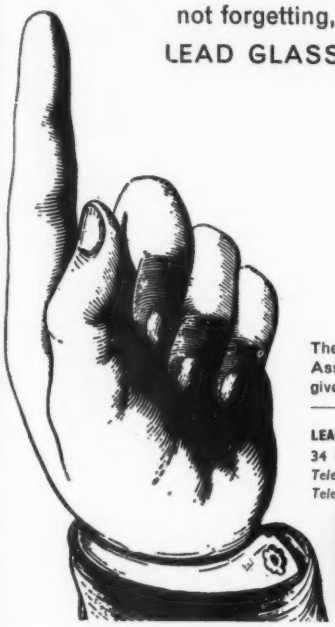

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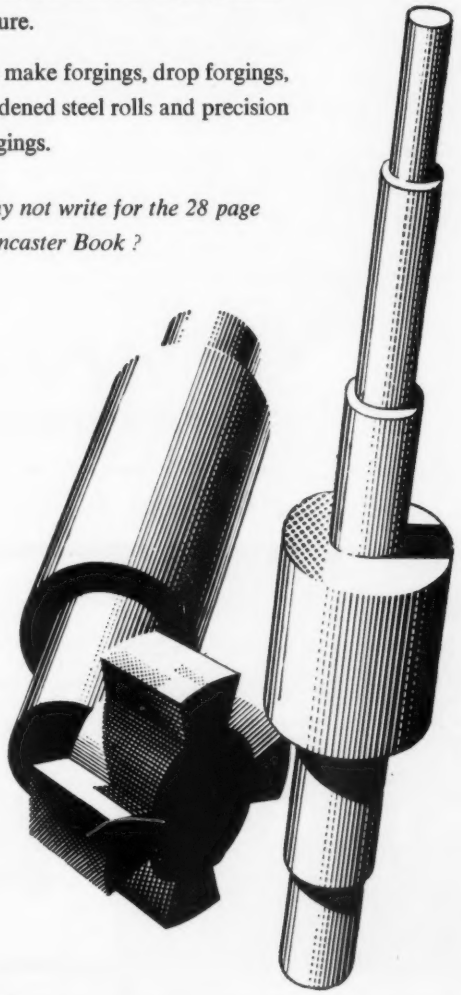

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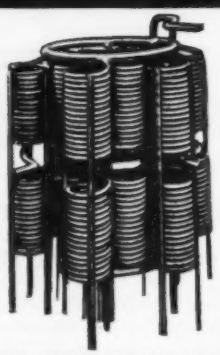

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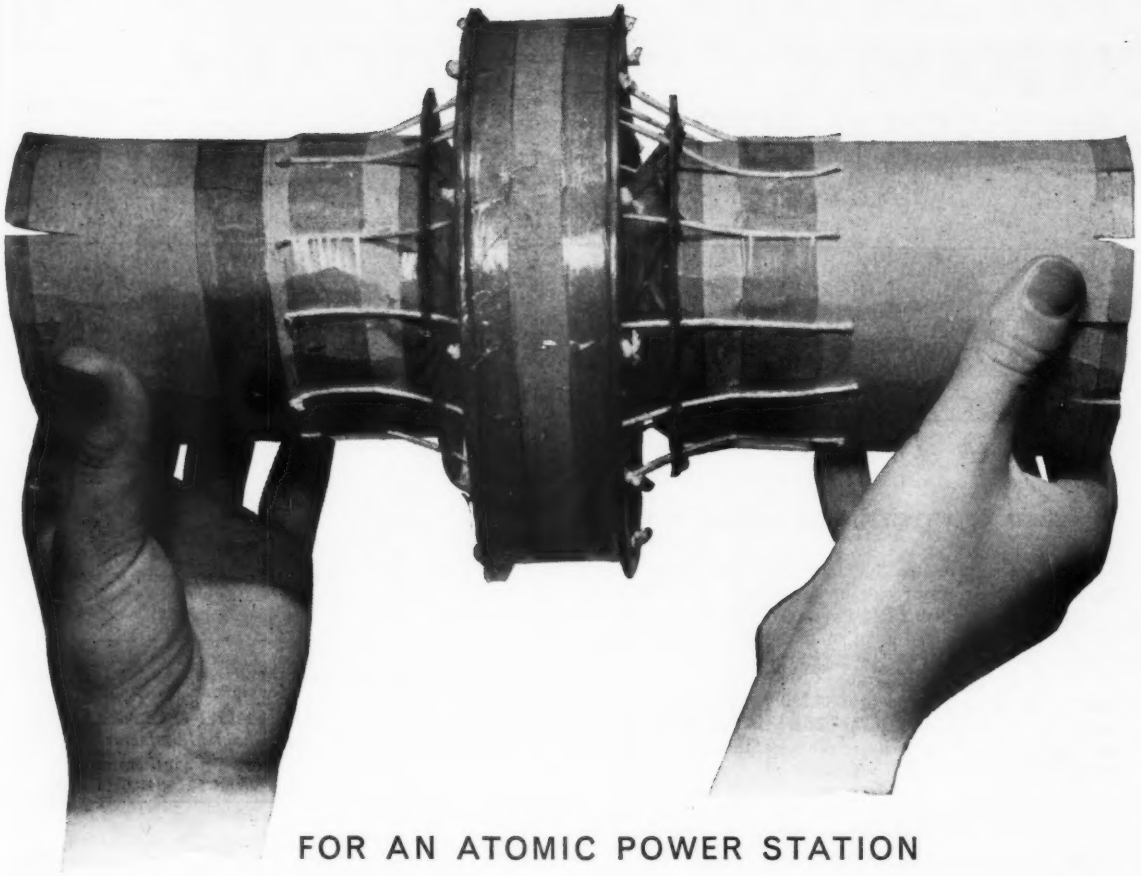

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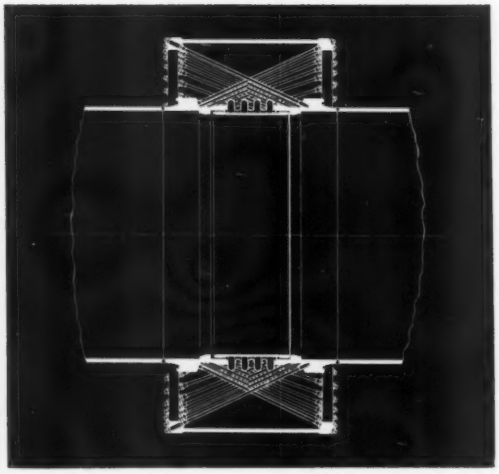

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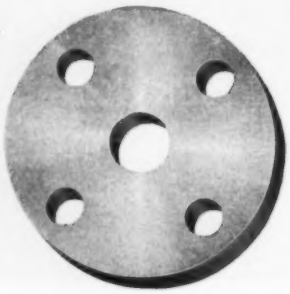

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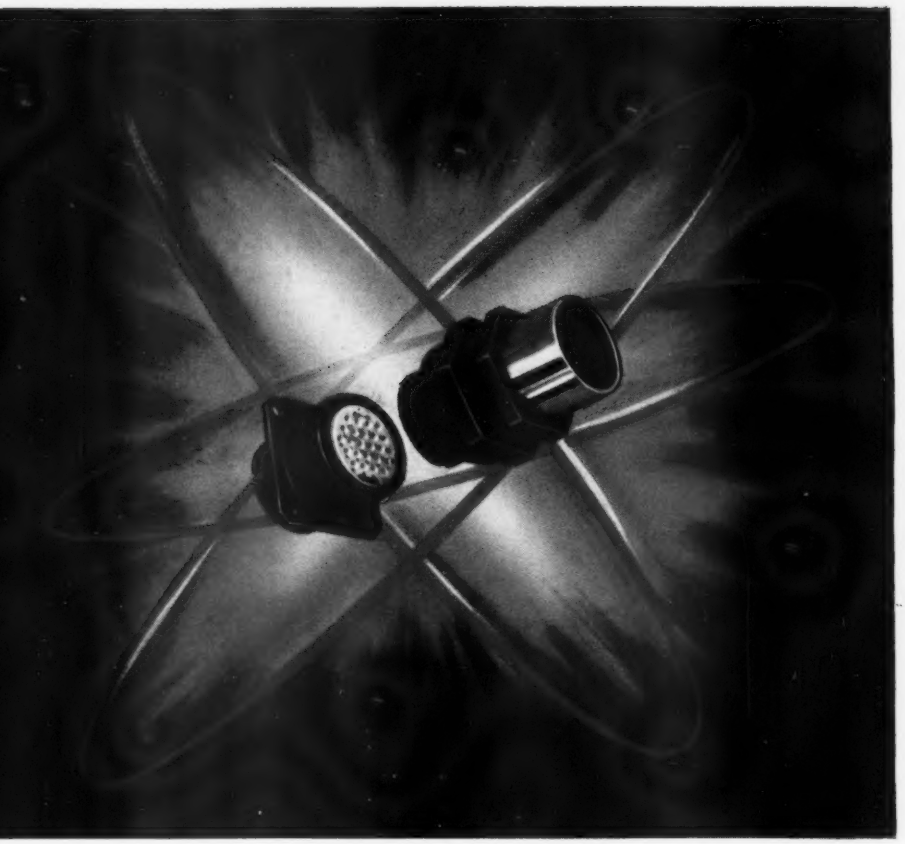

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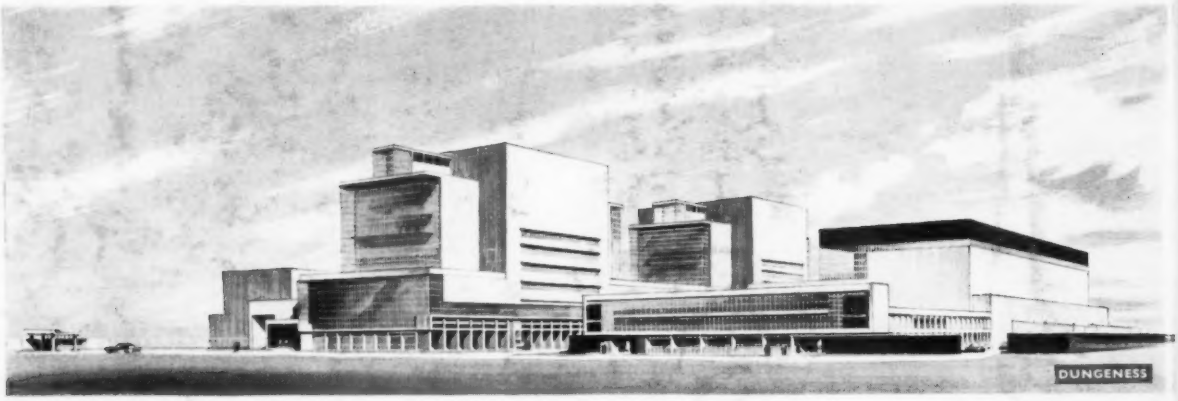

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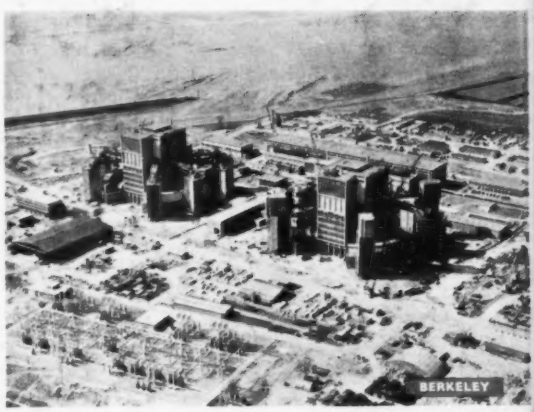

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